THE UNIVERSITY OF ALBERTA

DEVONIAN CHITINOZOA AND ACRITARCHA FROM EXPLORATORY OIL WELLS ON THE SHELF AND COASTAL REGION OF GHANA, WEST AFRICA

by

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A THESIS

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ABSTRACT

Sixty-eight species of Chitinozoa belonging to 15 genera, and 37 species of Acritarcha belonging to 17 genera from Devonian sediments of exploratory oil wells on the shelf and coastal region of Ghana, West Africa, are figured and described. Twenty species and three genera of the Chitinozoa, and twelve species and two genera of the Acritarcha appear to be new.

The Ghanaian chitinozoan and acritarch assemblages have several elements in common with those from the Devonian of Europe, North Africa, North America, and especially with an upper Lower Devonian (Emsian) to a lower Upper Devonian (Frasnian) assemblage from Brazil, South America.

Four tentative Chitinozoa assemblage zones have been proposed for the marine section of the Devonian sediments observed from the wells as follows, in descending order: "Zone D": Angochitina mourai Assemblage Zone; "Zone C": Angochitina devonica-Angochitina (Ramochitina) ramosi Assemblage Zone; "Zone B": Cladochitina varispinosa Assemblage Zone; "Zone A": Ancyrochitina sp. 6 Assemblage Zone.

Microfossil evidence indicates that a marine transgression from the westerly direction, with respect to the present magnetic pole position, occurred in Ghana during the late Early Devonian (Emsian) time. The sea was very shallow, of an epicontinental platform type and for a long period of time periodic fluctuations in water level ensued. Marine regression probably started during the early Late Devonian (Fras-

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Microfossil evidence indicates that a marine transgression from the southerly direction, with respect to the present magnetic pole position, occurred in Ghana during the late Early Devonian (Emsian) time. The sea was very shallow, of an epicontinental platform type and for a long period of time periodic fluctuations in water-level ensued. Marine regression probably started during the early late Devonian (Fras-

nian) and was slow. In the west, deltaic conditions probably followed the marine regression. Continental deposition followed the complete withdrawal of the Devonian Sea which was in turn followed by brackish water conditions.

This study indicates a single and probably a continuous sedimentation cycle during the Devonian period in Ghana. It appears that a restricted stratigraphic interval in the Middle Shale Formation, or Clay Shale, of the Accraian Series outcropping along the east coast of Ghana corresponds to the lower section of the marine sediments observed from the wells, and a restricted stratigraphic interval in the Takoradi Shale of the Sekondi Series outcropping along the west coast of Ghana corresponds to the upper section of the marine sediments and lower part of the overlying continental material. The Clay Shale carries macrofossils assigning an Early Devonian or Middle Devonian age to the Accraian Series and the Takoradi macrofossils, as well as plant fragments, have been used to date the Sekondi Series as Late Devonian or Early Carboniferous age. Several units in the Accraian Series and the Sekondi Series are probably synchronous and their lithologic dissimilarities are assumed to be reflections of local variations in the supply of clastic materials.

The four tentative Chitinozoa assemblage zones proposed by the writer for the marine Devonian sediments in Ghana correlate closely, both in microfossil content and diagnostic species ranges of the zones, with similar zones proposed by Lange (1967) for Devonian sediments in the Paranã Basin, Brazil, South America. Thus, this study reinforces the evidence of a common geologic setting for both sides of the Atlantic Ocean of West Africa and South America during the Devonian period.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOGRAPHIC PLATES

Frontispiece. Scanning Electron Micrograph of *Ancyrochitina* sp. cf. *A. ancyrea* Eisenack from the Devonian of Ghana, Magnification X1,500.

CHAPTER I

INTRODUCTION

Historical Background

The economic development of Ghana, West Africa, has often been closely associated with the coastal region. The early explorers were attracted to the country by the gold deposits in the coastal region and they named the country the Gold Coast. For several centuries this country was known by this name which described its immense economic potential. It was only in 1957 at Independence that the name of the country was changed to Ghana to reflect our African heritage.

In the Tano Basin in the south-west coast and the Keta Basin in the south-east coast of Ghana (Fig. 1) numerous oil seepages and gas shows occur in sediments of Cretaceous and Tertiary age. Recent petroleum exploration drillings in the Keta Basin and on the continental shelf have indicated that beneath thick Cretaceous and Tertiary sediments thick Paleozoic sediments, believed to be Devonian in age, are also potential reservoirs for petroleum deposits.

In 1966, under an oil exploration contract signed between the Ghana Government and the Industrial Export Company, Romania, two onshore wells were drilled in the Keta Basin which, hitherto, had been considered to be composed only of Cretaceous and Tertiary sediments. The first well drilled in the basin, Atiavi-1 well, was a stratigraphic

test well located at the central portion of the basin where geophysical data indicated about 8,000 feet thickness of sediments. The total depth of the well to the basement rocks of the Dahomeyan was about 5,000 feet. The lowermost 1,910 feet of the sediments encountered were Devonian in age.

Since 1968 the entire continental shelf of Ghana has been under concession for petroleum exploration programmes, and by 1970, eleven wells had been completed. Four of these wells on the shelf (Fig. 5), i.e. Signal Exploration and Development Company/Ghana 10-1 well, 13-1 well, and 13-2 well and Union Carbide/Ghana 19-2A well penetrated through Paleozoic sediments with lithologic characteristics similar to the Sekondi Series or the Accraian Series which crop out along the coast (Figs. 2-4). Data from these wells are as follows: Signal Exploration and Development Company/Ghana 10-1 well: total depth 9,715 feet (?), Paleozoic sediments 3,725 feet thickness (?); 13-1 well: total depth 9,000 feet, Paleozoic sediments 3,060 feet thickness; 13-2 well: total depth 9,550 feet, Paleozoic sediments 3,680 feet thickness; Union Carbide/Ghana 19-2A well: total depth 9,010 feet, Paleozoic sediments 2,370 feet thickness.

The occurrence of Paleozoic sediments in areas previously believed to be composed of only Cretaceous/Tertiary and Recent sediments is geologically significant. But perhaps, of more importance, a quantity of oil was reported from the Signal Exploration and Development Company/Ghana 10-1 well from two zones in the Paleozoic sediments with tested oil flow of 1,300 b/d of oil of 40 degree API gravity and 2,300 b/d of oil of 37 degree API gravity. Hydrocarbon shows have also been reported

from the Paleozoic sediments observed in the other wells.

Apart from its economic potentialities, the coastal region of Ghana as part of the Atlantic Coast of West Africa has special geological interest. The close similarity in geologic setting of both sides of the Atlantic Ocean off Africa and South America (Fig. 13) during the Paleozoic and Mesozoic eras has been used by the proponents of the Continental Drift Theory as strong supporting evidence for the theory.

The economic potentialities as well as international geological interest require the establishment of standard biostratigraphic successions and assemblages to be used as tools in calibration of the Ghanaian sedimentary column. Illustrations of the components of the assemblages will assist other geologists in the recognition of the diagnostic fossils. All of the illustrated fossils of this thesis are believed to be Devonian in age. Microfossils consisting of abundant chitinozoans, acritarchs, spores, tasmanitids, leiospheres and scolecodonts from the Paleozoic sediments from the Signal Exploration and Development Company/Ghana 10-1 well, Union Carbide/Ghana 19-2A well, and Ghana Geological Survey/Atiavi-1 well have been prepared for a preparation of a Special Geological Report for the Government of Ghana.

The chitinozoan and acritarch assemblage which will constitute Part One of the report to the Government of Ghana forms the basis of this dissertation. The spore assemblage will form Part Two and the tasmanites, leiospheres and scolecodonts will form Part Three of the report.

Objective and Scope of Thesis

It is believed that a detailed knowledge of the biostratigraphy of the Paleozoic sediments on the shelf and coastal region of Ghana will be the basis upon which their petroleum potentialities can be better assessed. The geologic knowledge of these sediments from this project will also be important in shedding some light on the geologic setting of the Atlantic coast of West Africa and of South America during the Devonian period.

The immediate objectives of this thesis toward fulfilling the above-mentioned goals are to establish biostratigraphic zonations for the Paleozoic sediments from the three wells (super) on the basis of the chitinozoan assemblage; to interpret the paleoecology of the various lithofacies with palynomorphic entities, viz: chitinozoans, acritarchs, and spores; to compare the Ghanaian chitinozoan and acritarch species from the wells studied with similar chitinozoan and acritarch species reported from better dated sediments in Europe, North Africa, North America, and South America in an attempt to establish specific age for the Paleozoic sediments observed from the various wells studied; to correlate the Ghanaian chitinozoan and acritarch assemblage with that of Brazil.

The scope of the thesis is to study the chitinozoans and the acritarchs recovered from the exploratory wells and identify the various species on the bases of the classification schemes proposed for the chitinozoans by Eisenack, and the acritarchs by Downie, Evitt and Sarjeant, and to interpret the ecologic significance of the assemblages within the framework of the present knowledge of the groups.

Spores found in sedimentary basins were probably endemic to the immediate geographic margins of the basins. The amount of spore diversity and abundance in sedimentary basins depends on wind direction and current patterns in the basins. The general distribution of the spores in relation to the chitinozoan and the acritarch assemblages from the wells may provide evidence on major paleoecologic changes during the deposition of the sediments.

Previous Work on Paleozoic Sediments Outcropping Along the Coast

Along the east and west coast of Ghana, Paleozoic clastic sediments tentatively dated as Lower or Middle Devonian age (the Accraian Series) and upper Devonian or Lower Carboniferous age (the Sekondi Series), occur as faulted blocks (Figs. 2-4). The estimated thickness of the Accraian Series is 2,865 feet (Saul *in* Saul *et al.*, 1963) and that of the Sekondi Series is 3,740-4,000 feet (Crow, 1952). Although these sediments are lithologically well known, the knowledge of their biostratigraphy is extremely limited. The scanty paleontologic work which has been done so far, on both series, has been restricted to the description of faunas and floras, from a single unit in each series. The material was not sufficiently diagnostic to give other than generalized limits to the age of the beds.

Davies (*in* Kitson, 1922) described some faunas from the Accra Shale (Middle Shale Formation, McCallien, 1962; Clay Shale, Harris, 1964) and suggested a Middle Devonian age for the Accra Shale and tentatively correlated the sediments with the Middle Devonian Hamilton Group of New York State. Later, however, a Lower Devonian age was proposed for the Accraian Series and they were correlated with the Lower Devonian Bokkveld

Series of South Africa (Kitson, 1928). Saul et al. (1963) described a faunal assemblage from the Accra Shale but no specific age was proposed for the rocks. Saul (in Saul et al., op cit.) stated, "... The fauna of the Accraian Series cannot be precisely correlated with any other Devonian fauna that has been studied. Nothing in the faunal assemblage can be correlated with certainty at the specific level with any known fossils, but the genera represented are well known in any Lower and Middle Devonian sequence.... The conclusion therefore is that the Accraian Series is of Lower to Middle Devonian age and cannot be accurately correlated with any strata of this age studied to date." Anderson et al. (1966) proposed an early Devonian age for the Accraian Series, based on a few mutationellid brachiopods collected from the Accra Shale.

The ages which have been suggested for the Sekondi Series are as tentative as that for the Accraian Series. Davies (in Kitson, 1922; 1928) on the basis of faunal assemblage from the Takoradi Shale suggested Lower Carboniferous position for the Sekondi Series. Cox (1946) proposed "Devonian or Lower Carboniferous age, perhaps slightly more suggestive of the Devonian" for the Takoradi Shale, based on faunal assemblage. Mensah and Chaloner (1971) suggested an early Carboniferous age for the Takoradi Shale, based on floral content.

It is clear from the work of these paleontologists that dating by macrofossils of the Paleozoic sediments outcropping along the coast of Ghana has been difficult and there appears to be a general lack of concensus of opinion on specific ages for either of the series. The problem is due largely to the fact that large sections of both the Accraian Series and the Sekondi Series are barren and the few macrofossils

which have been used to date them were usually too poorly preserved to allow more extensive analysis. No systematic biostratigraphic work involving any form of microfossils, however, has been attempted up to date for either the Accraian Series or the Sekondi Series.

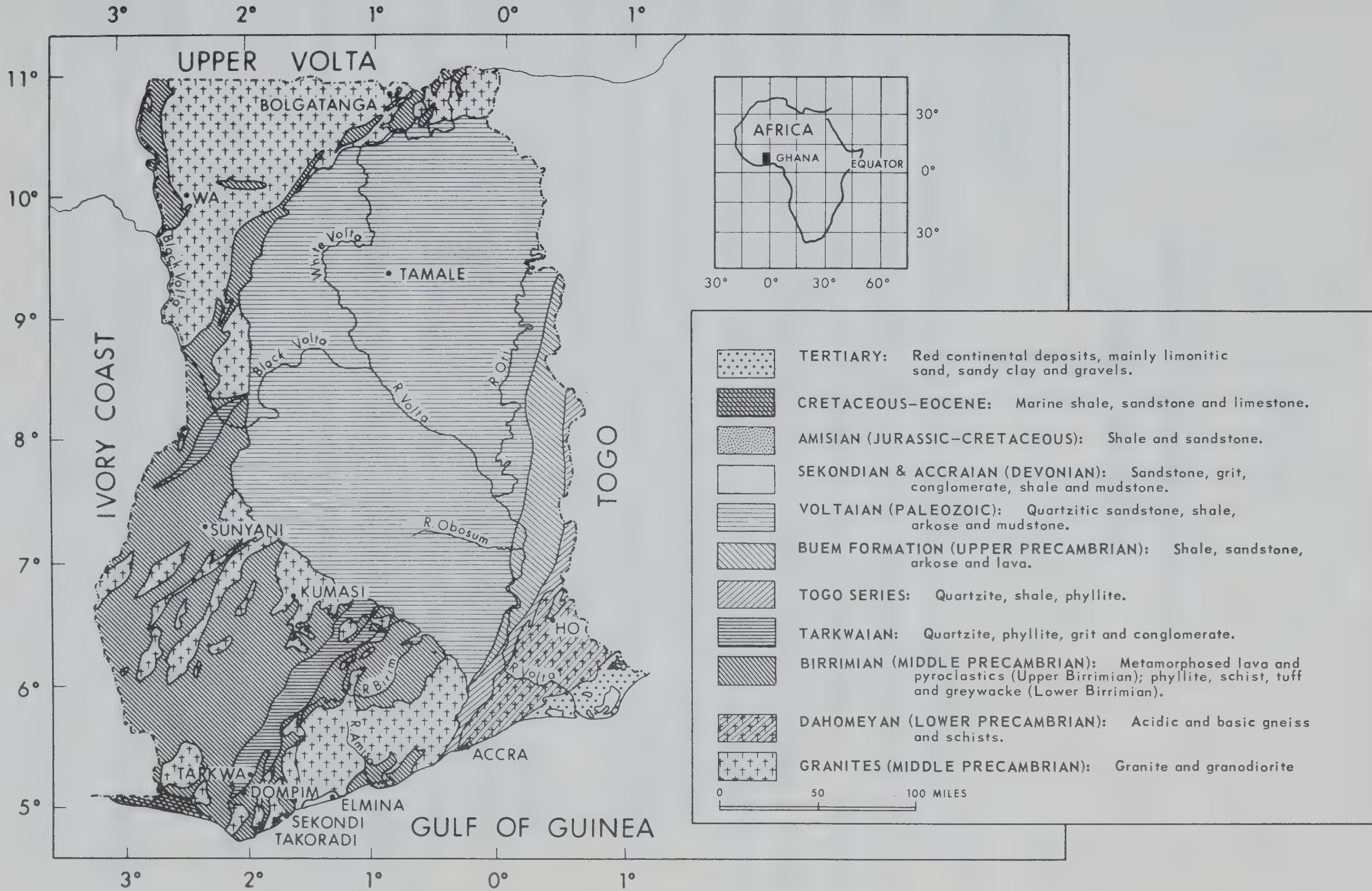

Figure 1. Geological Map of Ghana.

CHAPTER II

GEOLOGY OF THE COASTAL REGION OF GHANA, WEST AFRICA

General Statement

The Republic of Ghana, West Africa lies approximately between longitudes 3 degrees west and 1 degree east of the prime meridian and between latitudes 5-11 degrees north of the equator. It covers an area of approximately 92,000 sq. miles onshore with a continuous 9,200 square miles of continental shelf. Geologically, most of the major rock systems from early Precambrian to the Recent are exposed onshore (Fig. 1). The record of these rocks indicates several advances and retreats of the sea from the Precambrian era to Tertiary time.

The Precambrian rocks are represented in Ghana by the following systems, in ascending order: Dahomeyan, Birrimian, Tarkwaian, Togo and the Buem. Each of these systems is separated from the preceding one by a fold phase and unconformity. They have been metamorphosed by igneous bodies at various times, contemporaneously or immediately after folding.

The Paleozoic sediments at the coast are represented by the Accraian Series and the Sekondi Series. These rocks are extensively block-faulted and to a large measure, this has influenced the configuration of the present coastline (Figs. 2-4).

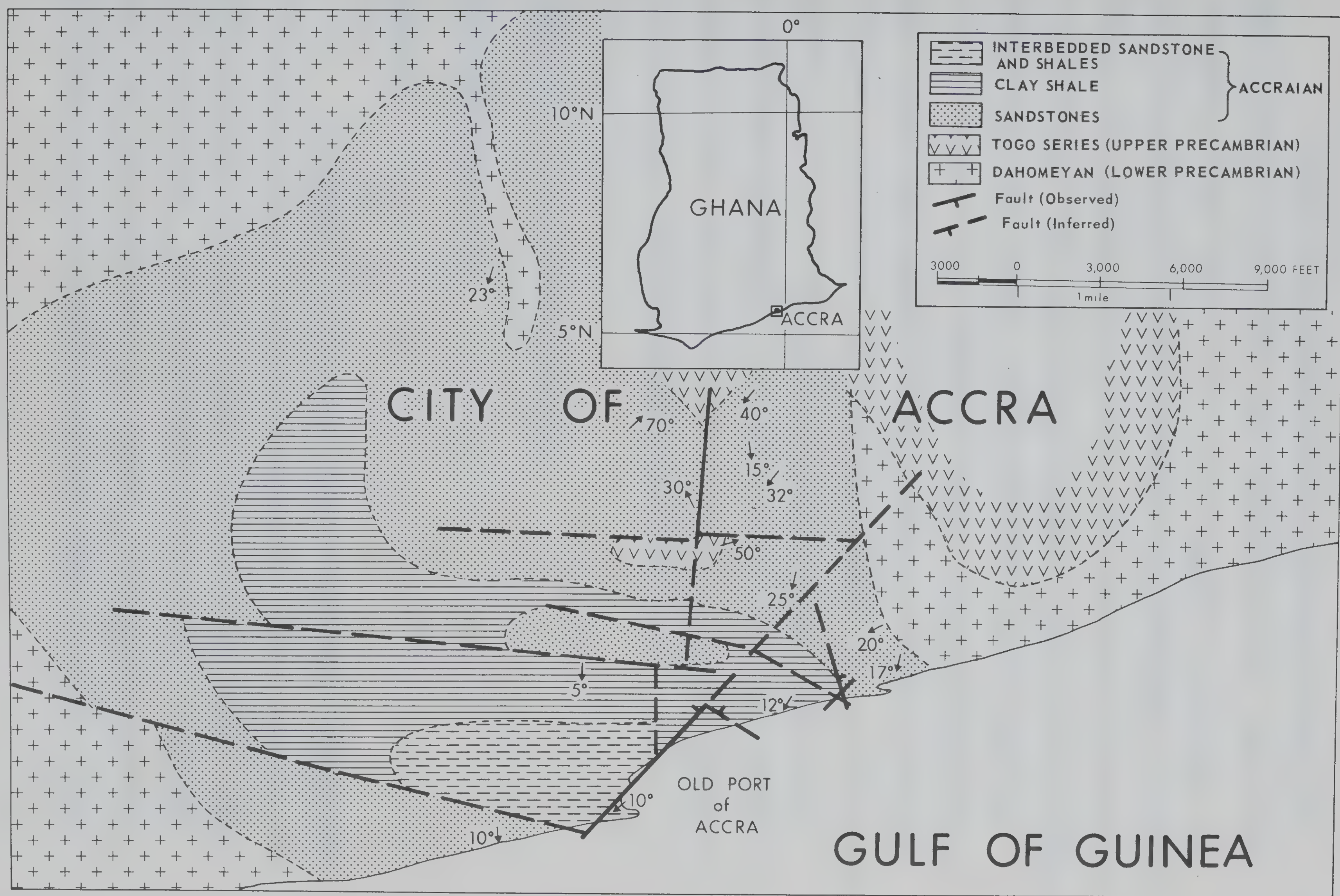

Figure 2. Geological Map of the Accraian Series (after Harris, 1964).

At the extreme southwestern and southeastern corners of Ghana on the coast, in the Tano Basin and the Keta Basin, respectively, Cretaceous/Tertiary sediments are found as remnants of sedimentary infill. Oil exploration drillings in the Tano Basin indicated a 10,000 feet thickness of sedimentary rocks along the coast and toward the border with the Ivory Coast. The oldest rocks encountered in the wells are of Middle Cretaceous age (Khan, 1970). In the Keta Basin, however, 2,840 feet thickness of Tertiary and Cretaceous sediments (Campanian-Maestrichtian) overlie unconformably about 1,910 feet thickness of Devonian sediments. A 230-foot thick dolerite intrusion of post-Devonian age and pre-Cretaceous age (Khan, 1970, p. 19) was encountered situated between the Devonian and the Cretaceous sediments. Southward, however, the Tertiary/Cretaceous sediments thicken considerably but no Devonian sediments were observed in the offshore well (K22-1) located near Keta (Fig. 5).

Stratigraphy of the Paleozoic Sediments

The Accraian Series

Lithology

The rocks of the Accraian Series are composed of interbedded shales and sandstones. They cover approximately 28 square miles in the vicinity of Accra and overlap Precambrian rocks of the Dahomeyan, Togo and the Buem systems. With the exception of some exposures along the coast, and in pits, excavations and trenches for engineering purposes, most of the rocks are covered by superficial deposits.

Kitson (1915) briefly mentioned the rocks of Accra in the Annual Geological Survey Report and later (1922) described them in detail at the 13th International Geological Congress, Brussels, Belgium. He divided the rocks into two main units: (1) sandstones at the two ends of the coastal section, separated by (2) clayey-shales and mudstones in the middle section of the coastline. This, in effect, implied that the two sandstone bodies at the coast are synchronous. Later work, however, indicated that they are not stratigraphically related and the one on the east coast is younger than the other.

Junner (1940) proposed four main subdivisions for the Accraian Series, in ascending order, as follows: (1a) Cross-bedded sandstones and pebbly grit; (1b) Alternating fine-grained sandstones and shales; (2) Relatively thick series of shales and mudstones; (3) Massive cross-bedded sandstone; (4) Alternating shales and thin-bedded micaceous sandstones.

Mason (1957) suggested three subdivisions of the Accraian Series as follows, in ascending order; (1a) Basal grit 32 feet thick (at coast); (1b) Sandstone 183 feet thick (at coast); (2) Clay-Shale 380 feet thick (at coast); (3) Interbedded sandstone (thickness?).

McCallien (1962) proposed a casual formational subdivision for the Accraian Series as follows, in ascending order; (a) Lower Sandstone Formation; (b) Middle Shale Formation; (c) Upper Sandstone-Shale Formation. According to McCallien, the Middle Shale Formation becomes more sandy upward and by an increase of sandstone interbeds, grades transitionally into the higher formation. The Upper Sandstone-Shale

Formation is usually intimately interbedded thin strata, but may show development of thick non-interbedded sandstones which are often coarse and distinctly pebbly.

Saul (in Saul et al., 1963) subdivided the Accraian Series into six units as follows, in ascending order: (1) Basal grit; (2) Lower sandstone; (3) Clay shale; (4) Lower interbedded clay shale and sandstone; (5) Upper sandstone; (6) Upper interbedded clay shale and sandstone. According to Saul (op. cit.) the sandstones and the basal grit are very quartzose. A total thickness of 2,865 feet was estimated for the series. Saul, however, indicated that the thicknesses and the relationships of the upper units are greatly complicated by faulting and it is not clear whether the upper sandstone is above or below the interbedded clay shale and sandstone. He suggested that the Accraian Series may be either an unrepeated sequence of sediments or a shallow syncline. Thus, his estimation of the thicknesses was based on considering the series to be an unrepeated sedimentary sequence. In the Union Carbide/Ghana 19-2A well located close to the outcrop of the Accraian Series (Fig. 5), the Devonian sequence encountered in the well is 2,370 feet thick.

Harris (1964) subdivided the Accraian Series into three groups, in ascending order, as follows: (a) Interbedded sandstones and shale; (b) Clay shale; (c) Sandstones. Harris' report on the Accraian Series was more or less a summary of various unpublished geologic reports on the series supplemented by geologic information obtained from extensive pitting, trenching and drilling for engineering purposes. Although all the various borings were logged in detail, no thicknesses were suggested for any of his three units. However, the areal extent of the

series was established for the first time and various faults in the area better delineated (Fig. 2).

Paleontology

Various species of lamellibranchs, brachiopods, trilobites and gastropods have been reported from the Accra Shale. Davis (in Kitson, 1922) recorded the following fauna from the Accraian Series: Dipleura (Homalonotus) dekayi; Nuculites (Cleidophorus); Palaeoneilo; Glyptodesma; Leiopteria; Lunulicardium; Conocardium; Hyolithes; Pleurotomaria(?); Lingula.

Plant fragments and chelae of crustaceans were also found in the Accraian Series. Based on this faunal assemblage, a Middle Devonian age was suggested for the Accraian Series and tentatively correlated with the Middle Devonian Hamilton Series of New York State. A Lower Devonian age was later proposed for the Accraian Series and it was suggested that the Accraian Series correlates with the Lower Devonian Bokkveld Series of South Africa (Kitson, 1928).

Saul et al. (op cit.) recorded the following fauna from the Accraian Series; Prismodictya; Discinisca; Lingula; terebratuloid; Leiopteria; Nuculana; Nuculites; Pleurodapsis; Ptychodesma; Stephenotus; Holopea; Plectonotus; Hyolithes; Tentaculites; homalonotid. Saul et al. compared the faunal assemblage in the Accraian Series with similar assemblages (at generic level) in the Hamilton Series of North America, in the Bokkveld Series of South Africa, in the Paraná basin of Brazil, in Bolivia and in North Africa, yet no age could be specifically proposed for the Accraian Series. However, according to Saul "... The terebratu-

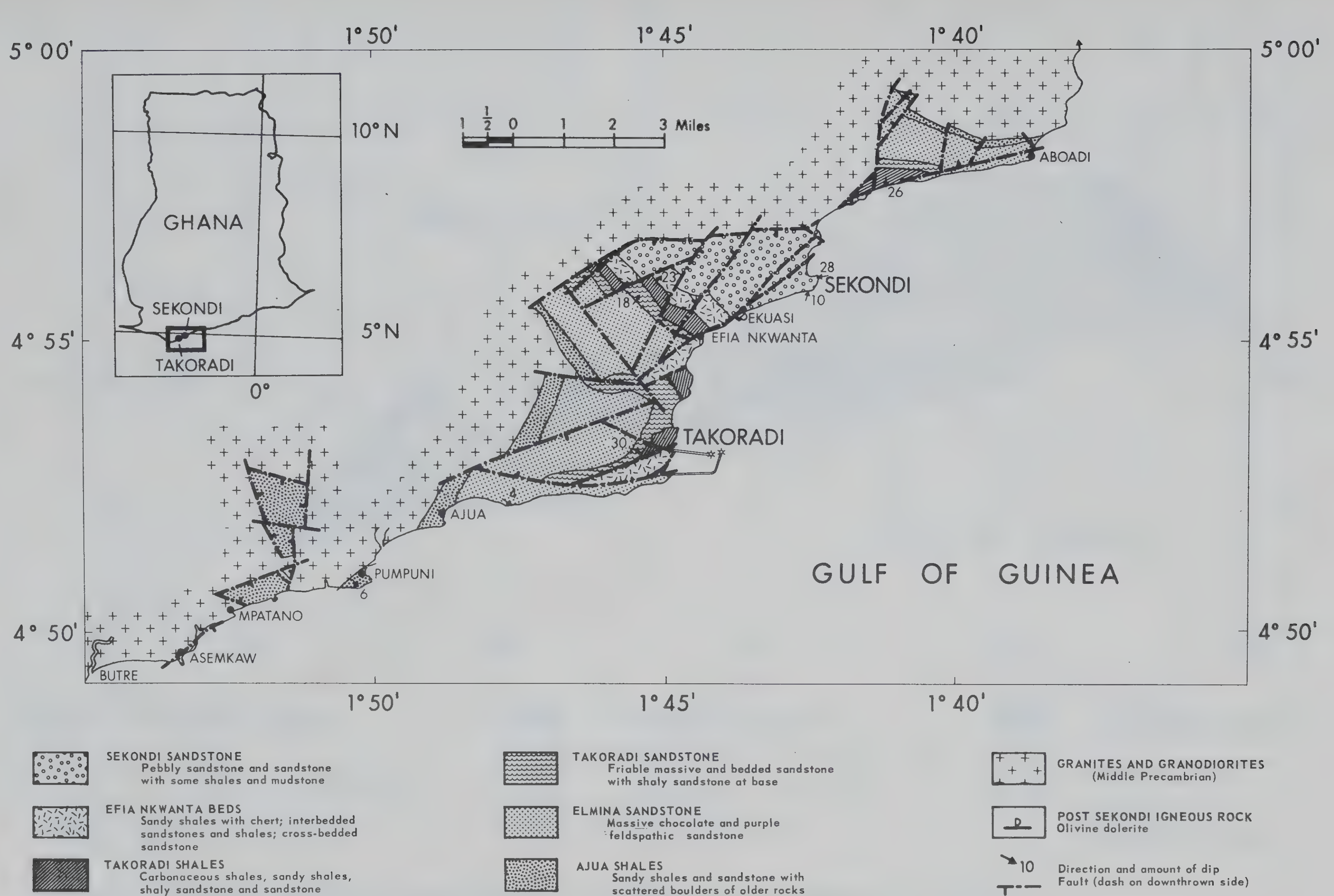

Figure 3. Geological Map of the Sekondi Series, Sekondi-Takoradi Area (after Crow, 1952).

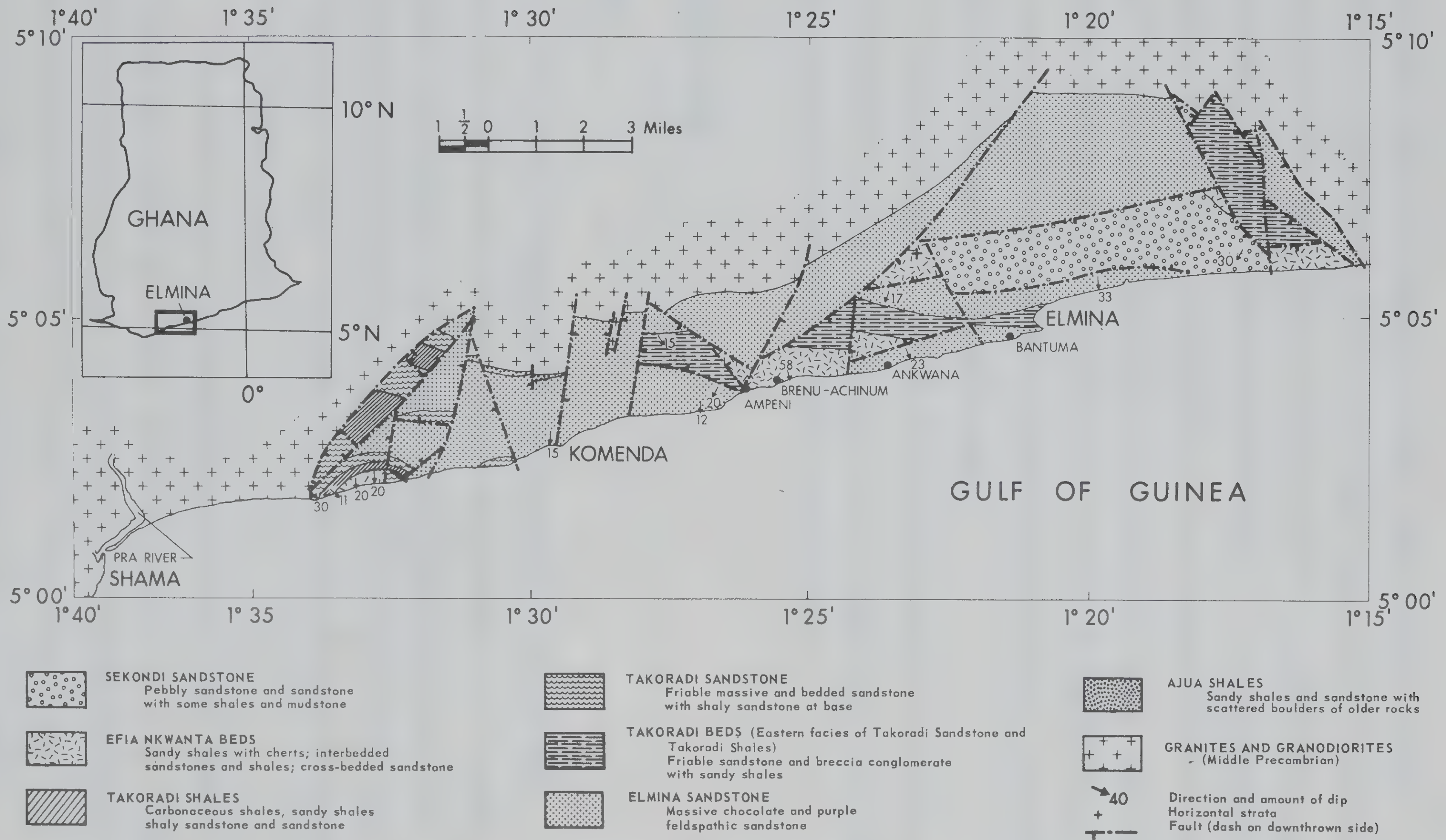

Figure 4. Geological Map of the Sekondi Series, Komenda–Elmina Area (after Crow, 1952).

loids show that the series cannot be younger than Givetian. Other fossils found in the series are not well enough known to aid in the dating problem, though most of the genera represented are in eastern North America more commonly found in Middle Devonian strata ..." Saul indicated that the tentative correlations of the Accraian Series with the Bokkveld and Hamilton Series should be rejected since no species was found common to the Accraian and Bokkveld or Hamilton Series. Thus, the Accraian Series is of Lower to Middle Devonian age but could not be accurately correlated with any strata of this age studied to date.

Anderson *et al*. (1966) described some specimens of terebratulid brachiopods of subfamily Mutationellinae collected from the Accra Shale and proposed Early Devonian age for the sediments.

The Sekondi Series

Lithology

The rocks of the Sekondi Series consist of feldspathic sandstones, siltstones and shales. They cover approximately 77 square miles onshore and extend in the aggregate along 43 miles of coastline as disconnected, block-faulted outcrops between Dixcove and Cape Coast on the west coast of Ghana. The rocks overlie unconformably Precambrian rocks of the Birrimian System.

Parkinson (1911) first mentioned the rocks of the Sekondi Series between Cape Coast and Sekondi as red and purple grits and arkoses, with ironstone partings and laminae of kaolin. Kitson (1916) reported oil shales from the Takoradi Shale. Junner (1924 *in* Crow, 1952) subdivided the Sekondi Series in Sekondi-Takoradi area as follows,

in ascending order: (1) Chocolate coloured arkose; (2) Highly friable sandstone; (3) Carbonaceous shale; (4) Alternating sandstone and shale with bands of chalcedony; (5) Upper pebbly argillaceous sandstones. Junner (1939) revised his previous classification of the series as follows, in ascending order: (1) Ajua Shales; (2) Elmina Sandstone; (3) Takoradi Shales; (4) Efia Nkwanta Beds; (5) Sekondi Sandstone. Crow (1952) mapped in detail the various outcrops of the Sekondi Series in order to confirm the stratigraphic successions proposed by Junner (op. cit.) and also to delineate accurately the extent of the various units. A summary of Crow's classification and the thicknesses of the various lithotypes is indicated in Table 1. A "serpentine-rich rock" of 8 feet thickness intrudes into the Sekondi Series as a sill and was dated between Carboniferous and Jurassic age. The extensive faulting in the area was tentatively dated by Crow as post-Jurassic in age.

With the exception of the Takoradi Shale and Takoradi Sandstone where a few fossils have been reported (see discussion on paleontology, p. 20) the other units of the Sekondi Series appear to be barren. Thus, using sedimentary structures and petrography of the sediments, Crow (op. cit.) reconstructed the paleoecology of the Sekondi Series as follows (Summary) " ... The rocks of the Sekondi Series were probably deposited in a large elongated valley descending to south-west. At the beginning the Ajua Shales were deposited under glacial conditions in a melt water lake, followed by a general inundation and the deposition of the Elmina Sandstone, still in a cold climate. After an emergence of the Elmina Sandstone, a river commenced to deposit the Takoradi beds in the valley. According to the variations in the elevation of the land, the deposits were fluviatile, estuarine, swamp, and possibly,

	Thickness in feet
S_6 Sekondi Sandstone.	
(b) Upper--Pebbly argillaceous and felspathic sandstones and conglomerates. (a) Lower--Massive quartzose sandstones and grits with subordinate shales and mudstones.	1,000
S_5 Efia Nkwanta Beds.	
(c) Upper--Thin bedded siltstone, shale, shaly sandstone, and some coarse sandstone, with nodules, bands, and lenses of chert	85
(b) Middle--Friable sandstone, both well bedded and massive, with interbedded mudstone and shale	315
(a) Lower--Cross-bedded, soft, fine-grained, pale purple, pink, grey, green, and cream sandstone	300
S_4 Takoradi Shales.	
Black and grey carbonaceous shales, sandy shales, and shaly sandstone, with interbedded grit and fine-grained sandstone, and with nodules of siderite and pyrite	650
S_3 Takoradi Sandstone.	
(b) Massive and bedded friable ferruginous sandstone with coarse-grained beds, breccia-conglomerate, and interbedded shales	500
(a) Thin-bedded, brittle, micaceous sandstone with sandy shale and some clay shale	100
S_2 Elmina Sandstone.	
Chocolate and purple felspathic micaceous sandstone, with coarse sandstone, conglomerate, shale, and mudstone near the base	1,000--1,200
S_1 Ajua Shales.	
Varved shales, sandy shales, and sandstones containing scattered boulders and pebbles with a coarse boulder bed at the base	140--200
MAJOR UNCONFORMITY Hornblende-granite of the Dixcove type. Biotite-granite of the Cape Coast type. Biotite- and hornblende-gneiss, schist, and granulite (Metamorphosed Birrimian)	

Table 1. Summary of the Lithology and Thicknesses of the Sekondi Series (after Crow, 1952).

deltaic. Silting up of the estuary, accompanied by increasing dryness, resulted in the formation of wind blown sands of the Lower Efia Nkwanta beds. The Middle and Upper Efia Nkwanta beds represent a partial resurgence of the river flow followed by a return to widespread mature conditions. The Lower Sekondi Sandstone represents a rejuvenation of the upper part of the river resulting in the erosion of its flood plain higher up, but renewed deposition lower down. The Upper Sekondi sandstones may indicate an additional rejuvenation with consequent rapid erosion, transportation, and deposition."

Paleontology

A few fossils have been described from the Sekondi Series. Davies (in Kitson, 1922) reported the following fossils from the Takoradi shales and Takoradi sandstones: *Orbiculoidea nitida* ? Phillips; *Posidonomya becheri* (Goldfuss); *Modiola* sp.; *Cypricardella* ? sp.; *Myalina* ? sp. According to Davies (op. cit.) *O. nitida* and similar species occur at many horizons, including the Devonian. On the other hand, *P. becheri* is a widespread Lower Carboniferous species and has been recorded from Europe, North America, and North Africa. Thus, based on the occurrence of *P. becheri* in the Takoradi Shale, Davies provisionally proposed Lower Carboniferous age for the sediments.

Fragmentary fish remains, including teeth of *Pleuracanthus*, scales, head bones, and operculum of palaeoniscids (cf. *Cladodus*) have also been identified by Whyte (in Kitson, 1928) from the Takoradi Shale. These fossils are Carboniferous or Devonian in age, according to Whyte.

Cox (1946) recorded the following fauna from the Takoradi

Shale: *Pleurotomaria* (*Ptychomphalina* ?) *batesi* Cox; *Palaeoneilo* (*Koenenia*) *junneri* Cox; *Nuculana* cf. *diversa* Hall; *Parallelodon cooperi* Cox; *Leiopteria hirsti* Cox; *Modiomorpha kitsoni* Cox; *Cypricardella tealei* Cox; *Sphenotus sekondiensis* Cox; *Lingulodiscina guineensis* Cox. Based on this faunal assemblage Cox suggested "Devonian or Carboniferous age, perhaps slightly more suggestive of the Devonian" for the Takoradi Shale.

Mensah and Chaloner (1971) described some plant fossils from the Takoradi Shale, among which were the following: *Archaeosigillaria essiponensis* Mensah and Chaloner; *Lepidodendron sekondiensis* Mensah and Chaloner. According to these workers these plant fossils show closer similarity to several Lower Carboniferous lycopod assemblages from North Africa than to the closest comparable species described from the Witteberg Series in the Cape (South Africa). A Lower Carboniferous age was thus suggested for the Takoradi Shale.

CHAPTER III

RESEARCH TECHNIQUES

Lithology of Samples

The samples which were used in this project were mostly cutting samples. The lithologic descriptions are included in the Appendix. They are generally shales, sandy shales and siltstones.

The quality of cutting-samples depends, more or less, on drilling mud and drilling techniques over which the writer has no control. Unfortunately, none of the electric logs from any of the wells were made available. For this reason the lithologic descriptions of the samples in the Appendix, as well as the lithologic boundaries for the wells are purely interpretative, based solely on visual observations of the samples under the binocular microscope.

Laboratory Procedures

Physical Disintegration

About 30 gms. of the sample were thoroughly washed with distilled water, and in the case of core samples or large cuttings, were crushed to "pea size" with cleaned pestle and mortar. The sample was then transferred into a 250 ml. polythene beaker with a fitting lid.

Chemical Disintegration

All the carbonate in the sample was removed with 10-15% dilute HCl. The complete removal of the carbonate is important since any carbonate left would form a gel-like precipitate in the next treatment with HF which would be difficult to remove. After the carbonate has been removed, the sample was washed thrice with distilled water by decantation process. Commercial HF (52% strength) was added to the sample to digest the silicate minerals. Period was 2-7 days depending on the induration of the sample. Occasionally, however, fresh HF was added to accelerate the digestion process. After the sample has been digested it was washed thrice with distilled water by decantation process. In the decantation process at any stage, the decanted solution was always checked to see whether microfossils were being missed.

Maceration Process

At the end of the silicate digestion with HF it was necessary to determine whether maceration was necessary and which procedure to use. For most of the oxidized or partly oxidized samples (red coloured samples) maceration was usually not necessary. The process was necessary to render the organic material in the greyish and dark grey shales translucent.

Concentrated HNO_3 (71%) was added to the sample for periods ranging from 8-15 minutes. Concentrated HNO_3 directly dissolves and converts the organic material into humic acid, thus, the process was closely controlled so that no palynomorphs were destroyed. Drops of the material were frequently put on a glass slide, covered with cover slip and examined under the microscope. When the organic fractions, particularly the acritarchs and spores, were sufficiently macerated the acid

was decanted and the material was washed thrice with distilled water. Occasionally, however, Schultze solution was used to macerate the organic material in some samples.

The humic acid formed as a result of the action of the acid on the organic material was removed by further treatment of the residue with 2% KOH for about 10 minutes. This process was also closely controlled. The KOH was decanted and the residue washed thrice with distilled water.

Heavy Liquid Separation

The residue was mixed with Zinc Bromide solution of about 2.3 S.G. and then centrifuged. The organic fraction collected at the top of the test tube was carefully pipetted, thoroughly washed with distilled water and stained with Safranin O using the filtration system of Neves and Dale (1963).

Filtration System of Neves and Dale

This system enables samples to be washed and stained without the transference of material from one receptacle to another. The system can actually be used from the maceration process if heavy liquid separation is not required.

The apparatus consists of a 150 ml. Buchner funnel with a fitted glass filter of 10-15 microns pore size. a 1000 ml. filtering flask with a side tube and a two-way rubber bulb. The funnel was fitted to the flask and the sample was added together with a copious amount of distilled water. The sample was then filtered, removing all the fine organic particles. The filtrate was periodically checked to see whether microfossils were not missed. After most of the fine organic particles

have been removed, the organic residue was stained and the excess stain removed. The filtration apparatus was cleaned with Schultze solution after each sample run.

In most samples the spores, leiospheres, and tasmanites were usually difficult to stain.

Mounting

Two drops of the concentrated residue were added to a 5 ml. phial into which has been placed 10 drops of distilled water and 10 drops of elvanol. The solution was thoroughly mixed and spread on No. 1, 22 x 50 mm. (preferably), or 22 x 22 mm. cover slip and allowed to dry under cover and then permanently mounted on glass slides using Canada Balsam. As many as 4-6 slides were prepared for most of the samples. The slides were labelled and left in warm oven of about 68°F for a couple of days.

Examination and Photomicrography

All the slides were studied using the Leitz Ortholux microscope 1011 equipped with an Orthomat camera attachment. The slides were placed on the mechanical stage of the microscope with the label to the right of the observer and the co-ordinates quoted in the text refer to the mechanical stage of this microscope with the horizontal scale given first followed by the vertical scale (e.g. 120.4/34.5). Each slide was thoroughly scanned for complete coverage but as the vertical movement of the mechanical stage could not cover the width of the slide, the position of the slide had to be reversed with the label to the left of the observer. Co-ordinates recorded in this position are prefixed

"L" (e.g. L109.8/30.7). New and well preserved "species" on each slide were photographed using Panatomic X film. By this "continuous photographic process" of specimens in each sample, comparison would be readily made with specimens in other samples and variations within species could be recognized. Processing of the photographs including the plates were carried out by the writer in the photographic studio in the Department of Geology.

Scanning Electron Micrography

The S4 Cambridge Stereoscan was used in this process. Specimens to be photographed with the S.E.M. (scanning electron microscope) were picked from the prepared samples with micropipette under the binocular microscope, washed in distilled water and mounted on the stub by means of fine, soft brush. No mounting medium was used apart from the glue on the stub left by the tape cover. The specimens were coated with about 150 Angstroms thick of carbon and gold in the Edwards' Vacuum Evaporator. All the illustrated micrographs are paratypes.

Repository

All the slides used in this project will be deposited in the Ghana Geological Survey Palynological Type Collections. The following procedure has been adopted in labelling the slides: (1) name of the company or organization which drilled the well; (2) location of the well; (3) sample number (in feet or meters); and (4) slide number prepared for a particular sample. Example (A): UC/19-2A/8840/4 which would be code for the following data:

Company: Union Carbide
Well Location: Ghana 19-2A
Sample Number: 8840 at 8,840 feet drilling depth
Slide Number: 4 of Sample 8840

Example (B) SE/10-1/7680/3

Company: Signal Exploration and Development Company
Well Location: Ghana 10-1
Sample Number: 7680 at 7,680 feet drilling depth
Slide Number: 3 of Sample 7680

Example (C) Atiavi-1/1460-1462/2

Organization: Ghana Geological Survey
Well Location: Atiavi-1
Sample Number: 1460-1462 at 1,460-1,462 meters drilling depth
Slide Number: 2 of Sample 1460-1462

Core samples are indicated by using suffix "C" for the Core Sample numbers. The interval cored is also indicated on the slide.

In the next paragraphs the following abbreviations have been used for the wells: UC/19-2A well (Union Carbide/Ghana 19-2A well; SE/10-1 well (Signal Exploration and Development Company/Ghana 10-1 well); A-1 well (Ghana Geological Survey Atiavi-1 well).

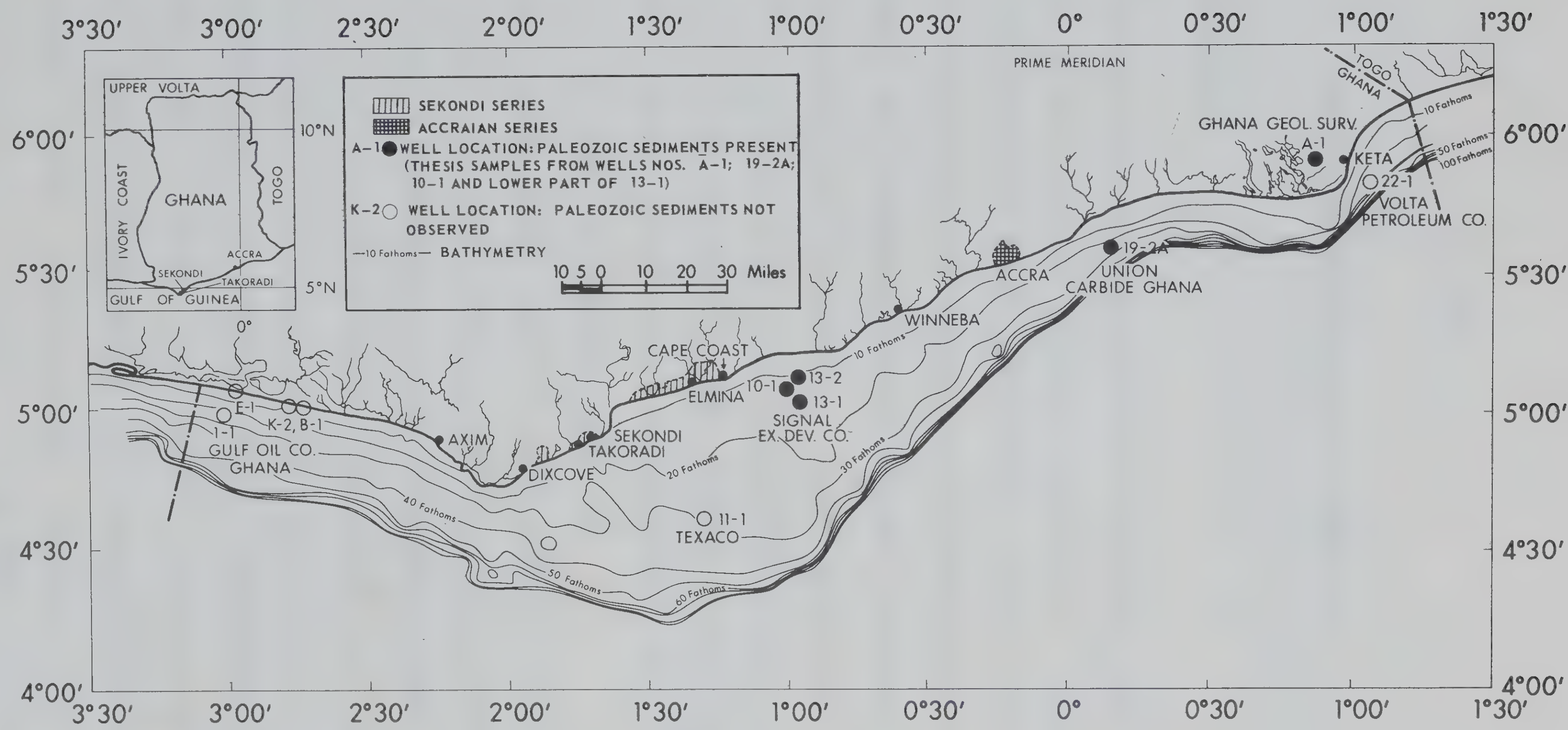

Figure 5. Location Map of Exploratory Oil Wells, Ghana.

CHAPTER IV

MICROFOSSIL DISTRIBUTION AND COMPARISON

Lithofacies Succession

The distribution of microfossils in the SE/10-1 well, UC/19-2A well and A-1 well indicates a general similarity of lithofacies successions. The lower sections of the Paleozoic sediments observed from the wells are marine and are composed of interbedded series of shales, sandstones, and siltstones with chitinozoans, acritarchs, spores, tasmanites, leiospheres, and scolecodonts. In the SE/10-1 well, the thickness of this section is 1,050 feet, in the UC/19-2A well located at about 83 miles ENE of the SE/10-1 well, the thickness of the section is 1,040 feet, and in the A-1 well located at about 54 miles ENE of the UC/19-2A well, it is 1,010 feet thickness (Fig. 5).

Overlying the marine facies in these wells are distinctly continental facies of interbedded shales, siltstones, and sandstones with occasional thin carbonaceous shaly beds containing abundant spore assemblages. This unit is 350 feet thick in the SE/10-1 well, 500 feet thick in the UC/19-2A well, and about 750 feet thick in the A-1 well.

Directly above the continental facies in the SE/10-1 well and the UC/19-2A well, barren intervals occur which are generally composed of coarse clastics with occasional chert. Some carbonate bands also occur in the barren intervals in the two wells. In the A-1 well however, the barren section was not observed. The thickness of the bar-

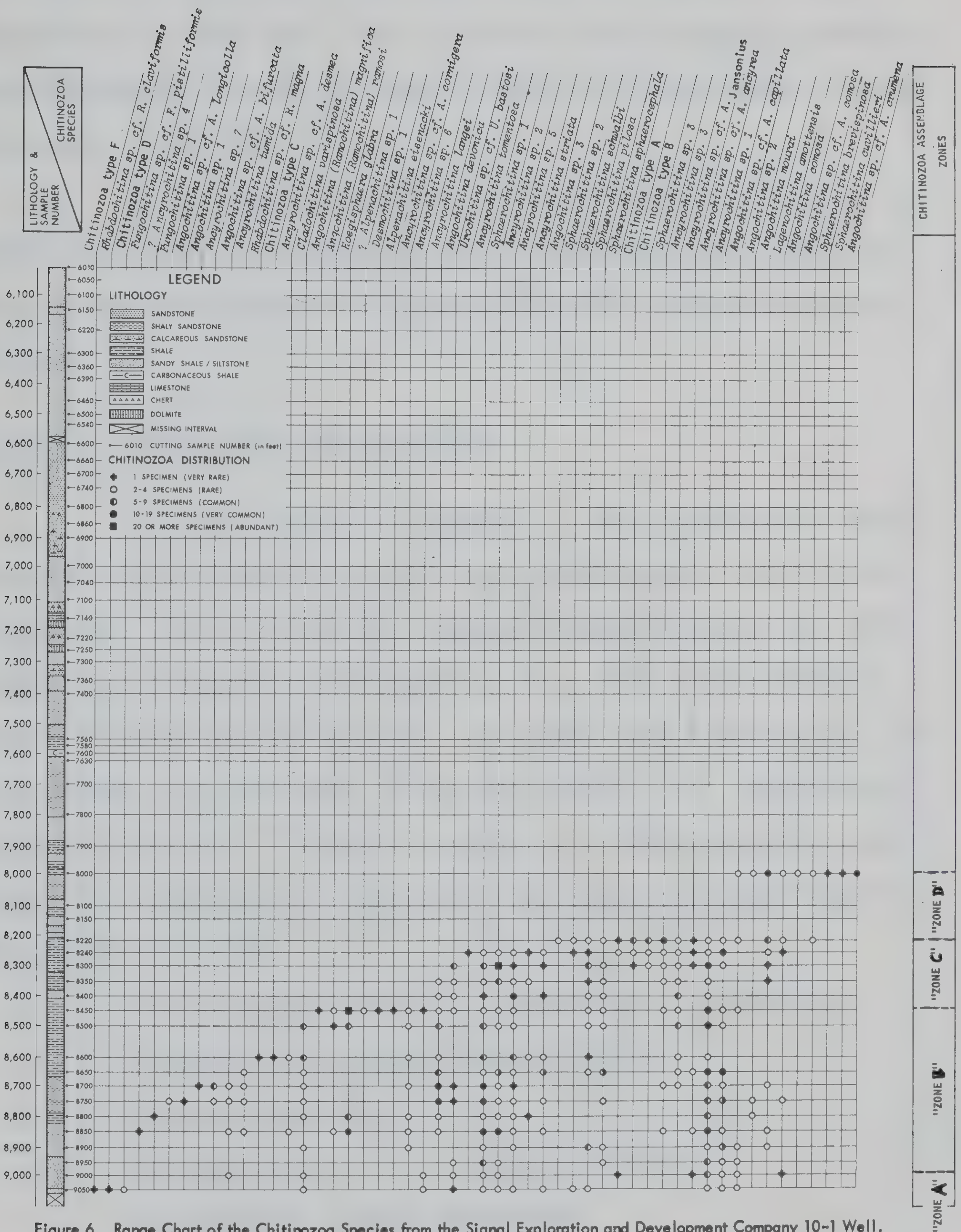

Figure 6. Range Chart of the Chitinozoa Species from the Signal Exploration and Development Company 10-1 Well.

ren section is 1,600 feet in the SE/10-1 well, and 850 feet in the UC/19-2A well, except for a thin calcareous clastic sediment containing some chitinozoans, poorly preserved acritarchs and some spores at 7,060 feet depth in the well.

In the uppermost portions of the Paleozoic sediments in the three wells distinct acritarch and spore assemblages occur. This section is very well developed in the A-1 well with a thickness of about 150 feet.

Chitinozoan Distribution and Comparison

The Range Charts in Figures 6, 7, and 8 indicate the distribution of the Chitinozoa in SE/10-1 well, UC/19-2A well, and A-1 well, respectively. Table 2 shows the comparative distribution of the chitinozoans from the various wells studied. Of a total of 68 Chitinozoa species observed from the wells 23 are common to all three wells, 16 are common to a combination of two wells, and 29 are unique to one or other of the wells. With the exception of a few species, the species which are restricted to a single well are very rare with only one or two specimens observed.

The following species are common to all three wells:

Alpenachitina eisenacki Dunn and Miller

?*Alpenachitina* sp. 1

Ancyrochitina sp. cf. *A. ancyrea* Eisenack

Ancyrochitina striata Taugourdeau

Ancyrochitina tomentosa Taugourdeau and Jekhowsky

Ancyrochitina sp. cf. *A. cornigera* Collinson and Scott

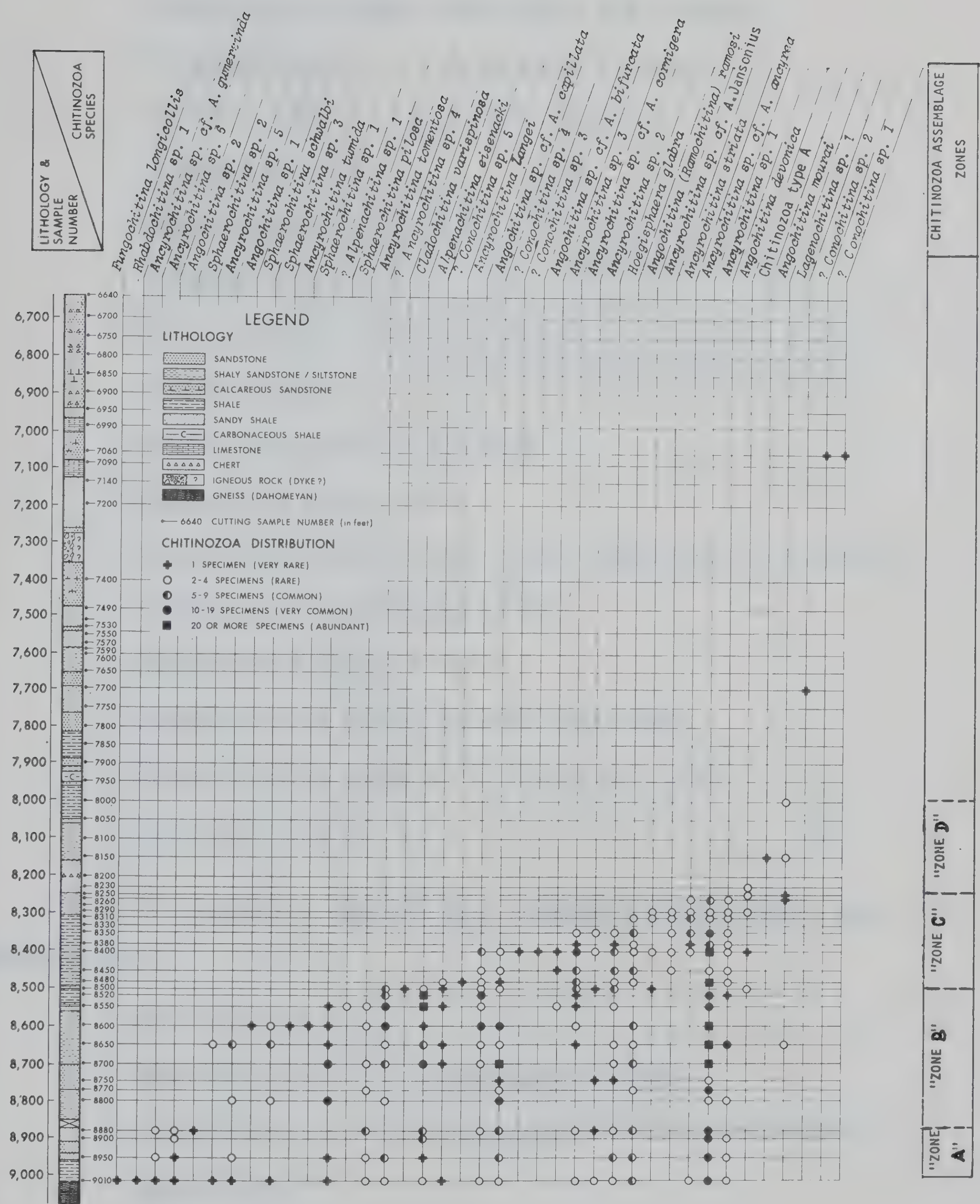

Figure 7. Range Chart of the Chitinozoa Species from the Union Carbide/Ghana 19-2A Well.

Ancyrochitina langei Sommer and van Boekel

Ancyrochitina tumida Taugourdeau and Jekhowsky

Ancyrochitina sp. cf. *A. spinosa* Eisenack

Ancyrochitina sp. cf. *A.* sp. Jansonius

Ancyrochitina sp. 1

Ancyrochitina sp. 2

Ancyrochitina sp. 3

?*Ancyrochitina* sp. 4

Ancyrochitina sp. 6

Angochitina devonica Eisenack

Angochitina mourai Lange

Angochitina (*Ramochitina*) *ramosi* (Sommer and van Boekel)

Cladochitina varispinosa Lange

Hoegisphaera glabra Staplin

Sphaerochitina pilosa Collinson and Scott

Sphaerochitina schwalbi Collinson and Scott

Sphaerochitina sp. 1

The following species are common to SE/10-1 well, and UC/19-2A well:

Ancyrochitina sp. 5

Angochitina sp. cf. *A. capillata* Eisenack

Angochitina sp. cf. *A. bifurcata* Collinson and Schwalb

Angochitina sp. 1

Angochitina sp. 2

Sphaerochitina sp. 2

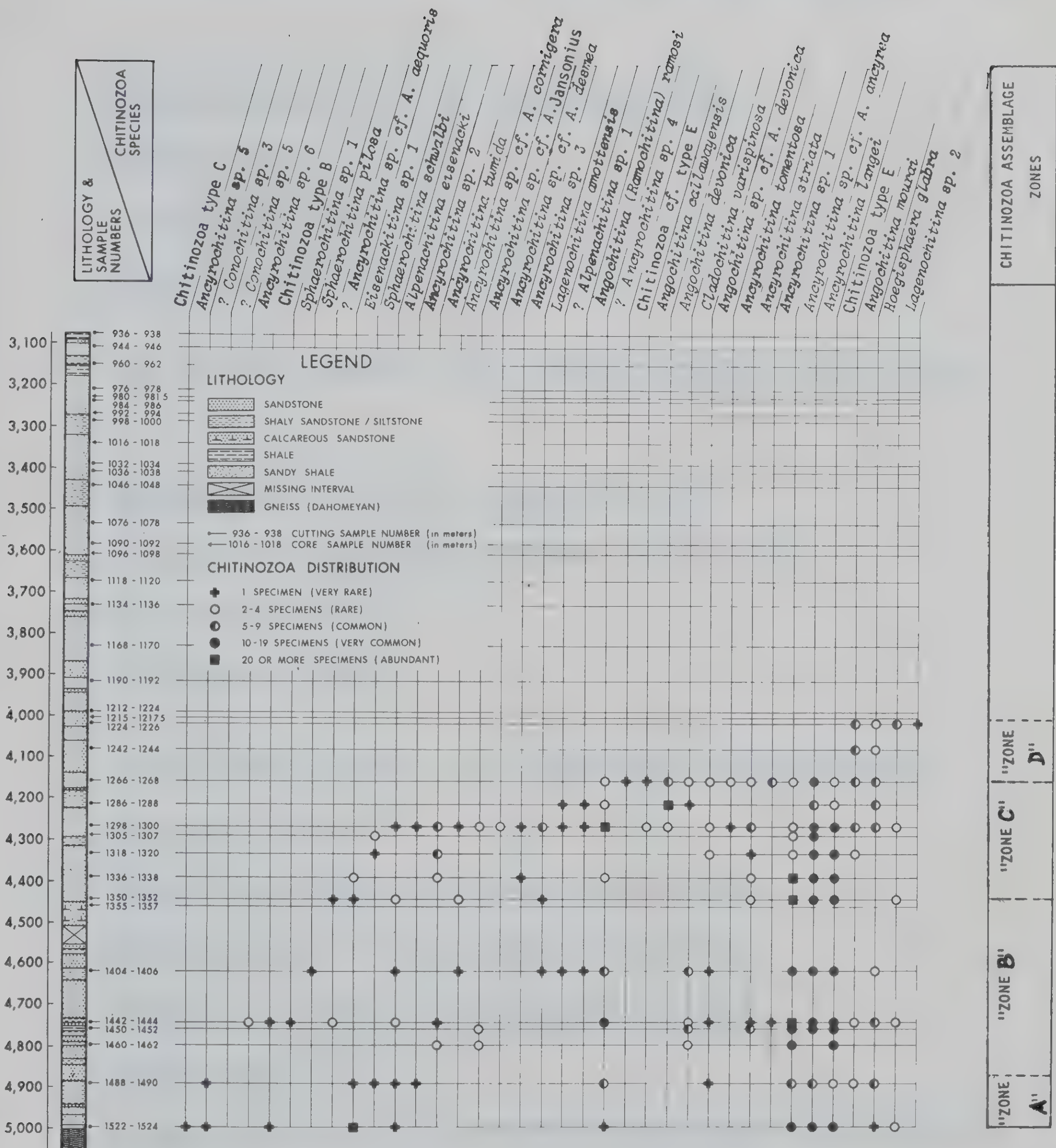

Figure 8. Range Chart of the Chitinozoa Species from the Atiavi-1 Well.

Sphaerochitina sp. 3

Chitinozoan type A

The following species are common to UC/19-2A well, and A-1 well:

Ancyrochitina sp. cf. *A. gumersinda* Cramer

Angochitina sp. 4

?*Conochitina* sp. 3

?*Conochitina* sp. 5

The following species are common to SE/10-1 well and A-1 well:

Ancyrochitina sp. cf. *A. desmea* Eisenack

Lagenochitina amottensis Grignani and Mantovani

Chitinozoan type B

Chitinozoan type C

The following species are restricted to SE/10-1 well:

Ancyrochitina sp. 7

Angochitina comosa Taugourdeau and Jekhowsky

Angochitina sp. cf. *A. crumena* Taugourdeau

Angochitina (*Ramochitina*) *magnifica* (Lange)

Desmochitina sp. 1

Fungochitina sp. cf. *F. pistilliformis lata* Taugourdeau and Jekhowsky

Rhabdochitina sp. cf. *R. magna* Eisenack

Rhabdochitina sp. cf. *R. claviformis* Taugourdeau

CHITINOZOA SPECIES / WELL NUMBER	SIGNAL EXPLORATION AND DEVELOPMENT COMPANY GHANA 10-1 WELL	UNION CARBIDE GHANA 19-2A WELL	ATIAVI-1 WELL
Alpenachitina eisenacki Dunn & Miller	+	+	+
? *Alpenachitina sp. 1*	+	+	+
Ancyrochitina sp. cf. A. ancyrea Eisenack	+	+	+
Ancyrochitina striata Taugourdeau	+	+	+
Ancyrochitina sp. cf. A. cornigera Coll. & Scott	+	+	+
Ancyrochitina langei Sommer & van Boekel	+	+	+
Ancyrochitina cf. A, gumersinda Cramer		+	+
Ancyrochitina tomentosa Taug. & Jekh.	+	+	+
Ancyrochitina sp. cf. A. spinosa Eisenack	+	+	+
Ancyrochitina sp. cf. A. desmea Eisenack	+	?	+
Ancyrochitina tumida Taug. & Jekh.	+	+	+
Ancyrochitina sp. cf. A. sp. Jansonius	+	+	+
? *Ancyrochitina sp. cf. A. aequoris* Urban & Kline			+
Ancyrochitina sp. 1	+	+	+
Ancyrochitina sp. 2	+	+	+
Ancyrochitina sp. 3	+	+	+
? *Ancyrochitina sp. 4*	+	+	+
Ancyrochitina sp. 5	+	+	+
Ancyrochitina sp. 6	+	+	+
Ancyrochitina sp. 7	+		
Angochitina devonica Eisenack	+	+	+
Angochitina sp. cf. A. devonica Eisenack			+
Angochitina callawayensis Urban & Kline			+
Angochitina mourai Lange	+	+	+
Angochitina (Ramochitina) ramosi Sommer & van Boekel	+	+	+
Angochitina (Ramochitina) magnifica Lange	+		
Angochitina sp. cf. A. capillata Eisenack	+	+	
Angochitina sp. cf. A. bifurcata Coll. & Schwalb	+	+	
Angochitina sp. cf. A. crumena Taugourdeau	+		
Angochitina sp. cf. A. longicolla Eisenack	+		
Angochitina comosa Taug. & Jekh.	+		
Angochitina sp. 1	+	+	
Angochitina sp. 2	+	+	
Angochitina sp. 3	+		
Angochitina sp. 4		+	+
Cladochitina varispinosa Lange	+	+	+
? *Conochitina sp. 1*		+	
? *Conochitina sp. 2*		+	
? *Conochitina sp. 3*		+	+
? *Conochitina sp. 4*		+	
? *Conochitina sp. 5*		+	
Desmochitina sp. 1	+		
Eisenachitina sp. 1			+
Fungochitina sp. cf. F. pistilliformis lata Taug. & Jekh.	+		
Fungochitina longicollis Taug. & Jekh.		+	
Fungochitina sp. 1	+		
Hoegishaera glabra Staplin	+	+	+
Lagenochitina amottensis Grig. & Mantovani	+		+
Lagenochitina sp. 1		+	
Lagenochitina sp. 2			+
Rhabdochitina sp. cf. R. magna Eisenack	+		
Rhabdochitina sp. claviformis Taugourdeau	+		
Rhabdochitina sp. 1		+	
Sphaerochitina pilosa Coll. & Scott	+	+	+
Sphaerochitina schwalbi Coll. & Scott	+	+	+
Sphaerochitina brevispinosa Grig. & Mantovani	+		
Sphaerochitina sphaerocephala Eisenack	+		
Sphaerochitina cuvillieri Taugourdeau	+		
Sphaerochitina sp. 1	+	+	+
Sphaerochitina sp. 2	+	+	
Sphaerochitina sp. 3	+	+	
Urochitina sp. cf. U. bastosi van Boekel	+		
Chitinozoa type A	+	+	
Chitinozoa type B	+		+
Chitinozoa type C	+		+
Chitinozoa type D	+		
Chitinozoa type E			+
Chitinozoa type F	+		

Table 2. Comparative Distribution of the Chitinozoa Species from the Various Wells Studied.

Sphaerochitina brevispinosa Grignani and Mantovani

Sphaerochitina sphaerocephala Eisenack

Sphaerochitina cuvillieri Taugourdeau

Urochitina sp. cf. U. bastosi van Boekel

Chitinozoan type D

Chitinozoan type E

The following species are restricted to UC/19-2A well:

?Conochitina sp. 1

?Conochitina sp. 2

?Conochitina sp. 4

Fungochitina longocollis Taugourdeau and Jekhowsky

Lagenochitina sp. 1

Rhabdochitina sp. 1

The following species are restricted to A-1 well:

?Ancyrochitina sp. cf. A. aequoris Urban and Kline

Angochitina sp. cf. A. devonica Eisenack

Angochitina callawayensis Urban and Kline

Angochitina sp. 5

Eisenachitina sp. 1

Lagenochitina sp. 2

Chitinozoan type E

Acritarch Distribution and Comparison

A total of 37 acritarch species were observed from the three wells studied. With the exception of a few acritarch species which appear

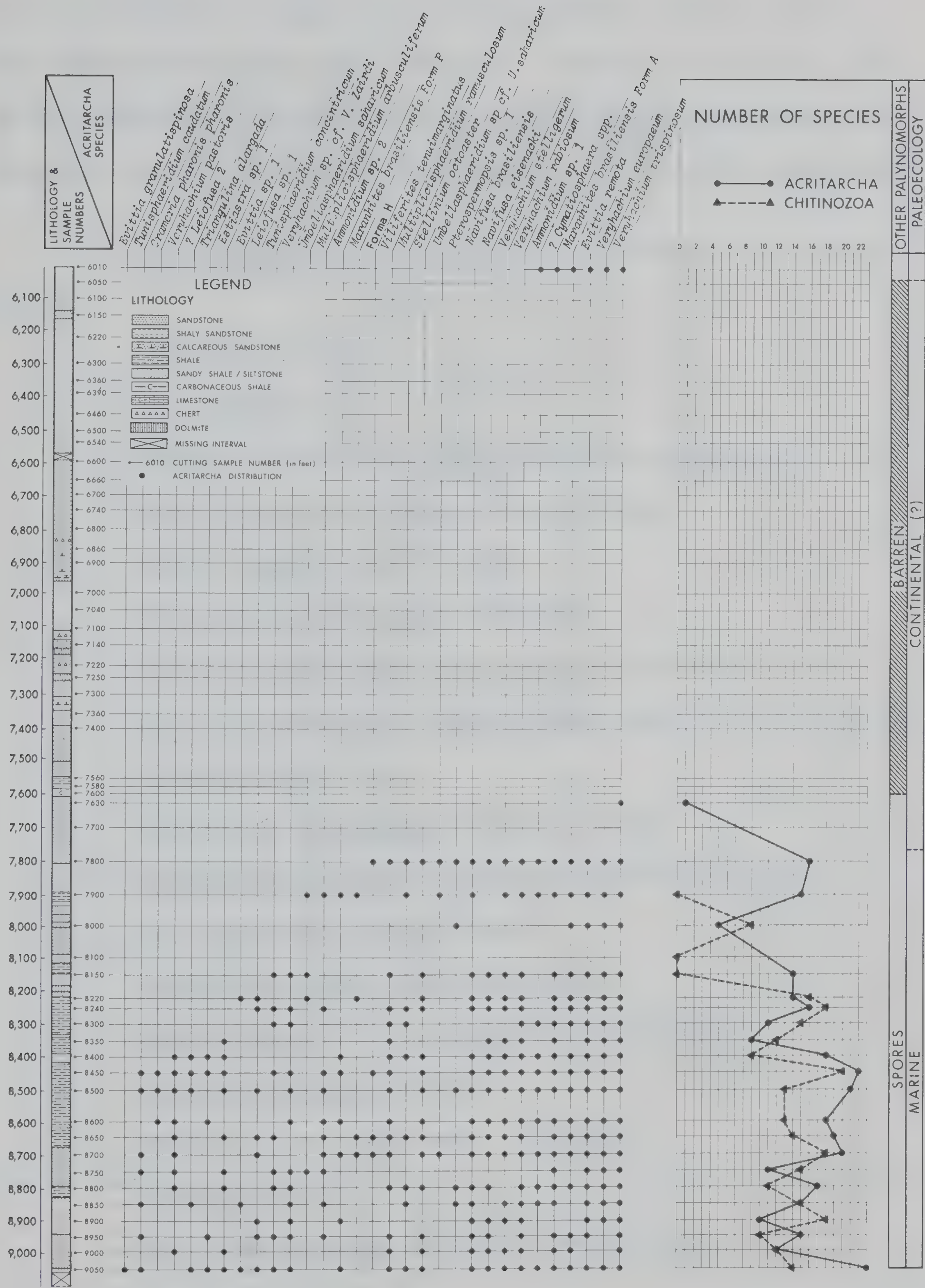

Figure 9. Range Chart of the Acritarcha Species from the Signal Exploration and Development Company 10-1 Well, General Distribution of Spores, Relationships of Association between Observed Number of Chitinozoa Species and Acritarcha Species, and Summary of Paleoecology.

to be restricted to a single well the rest of the acritarch species occur common to all three wells (Table 3). Figures 9, 10, and 11 show the distribution of the acritarchs in relation to the chitinozoans and the spores in the SE/10-1 well, UC/19-2A well and A-1 well, respectively.

The following acritarch species are common to all three wells:

Ammonidium sp. 1

Ammonidium sp. 2

Crameria pharoanis pharoanis (Deunff) Jardiné *et al.*

Evittia granulatispinosum (Downie) Lister

Evittia remota (Deunff) Lister

Micrhystridium stellatum Deflandre

Multiplicisphaeridium ramusculosum (Deflandre) Lister

Multiplicisphaeridium arbusculiferum (Downie) Staplin *et al.*

?*Cymatiosphaera* spp.

Veryhachium trispinosum (Eisenack) Cramer

Veryhachium europaeum Stockmans and Willière (Cramer)

Veryhachium stelligerum Deunff

Veryhachium lairdi (Deflandre) Deunff

Veryhachium sp. cf. *V. lairdi* (Deflandre) Deunff

Veryhachium pastoris Deunff

Veryhachium rabiosum Cramer, restricted

Estiastra sp. 1

Stellinium octoaster (Staplin) Jardiné *et al.*

Pterospermopsis sp. 1

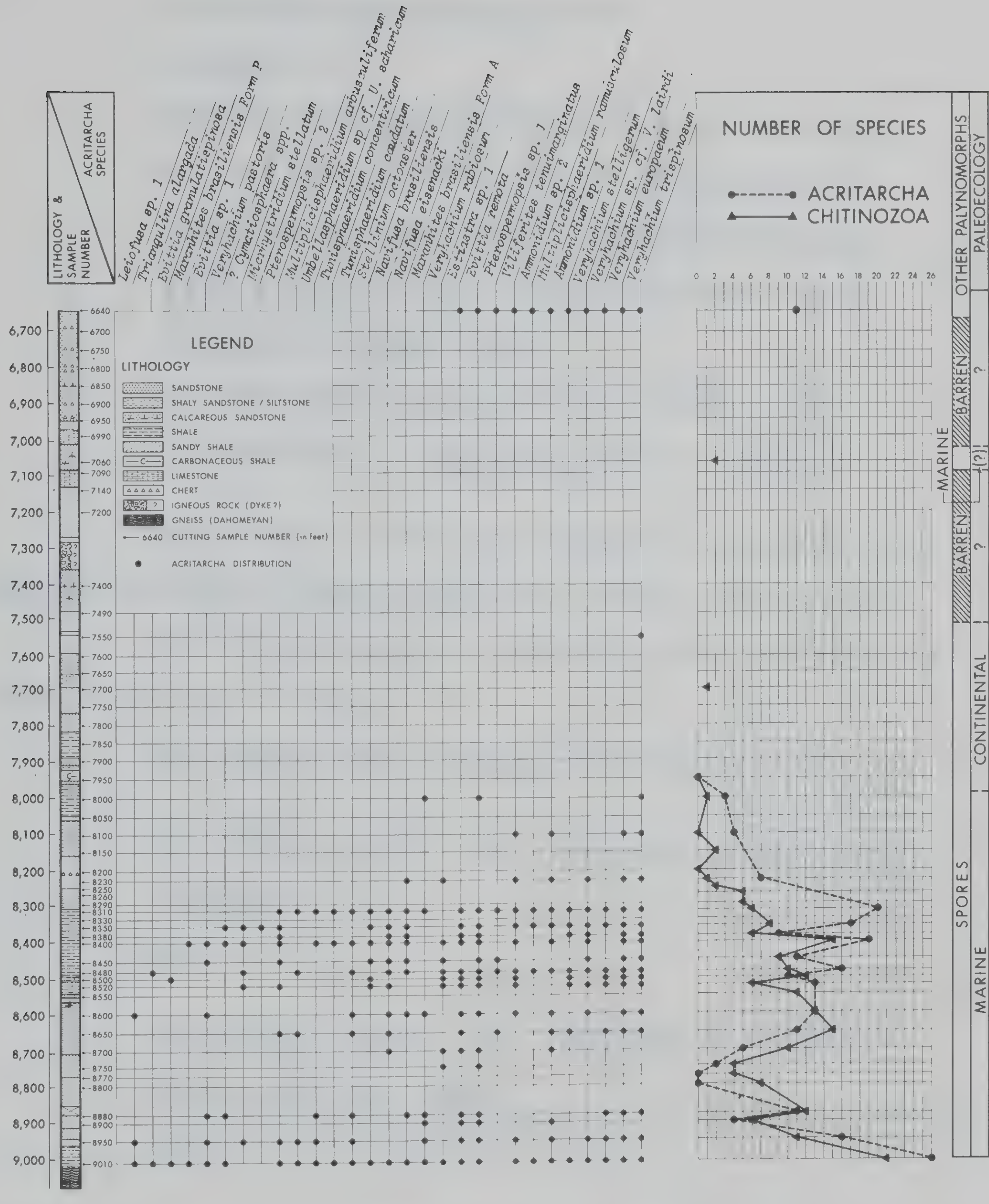

Figure 10. Range Chart of the Acritarcha Species from the Union Carbide/Ghana 19-2A Well, General Distribution of Spores, Relationships of Association between Observed Number of Chitinozoa Species and Acritarcha Species, and Summary of Paleoecology.

Viliferites tenuimarginatus Brito

Leiofusa sp. 1

Navifusa brasiliensis (Brito and Santos) Combaz et al.

Navifusa eisenacki (Brito and Santos) Combaz et al.

Maranhites brasiliensis Form A (Brito) Daemon et al.

Maranhites brasiliensis Form P (Brito) Daemon et al.

Triangulina alargada Cramer

Tunisphaeridium caudatum Deunff and Evitt

Tunisphaeridium concentricum Deunff and Evitt

Most of these species occur commonly to abundantly. Triangulina alargada and Pterospermopsis sp. 1 occur rather sparingly.

The following species was observed from SE/10-1 well, and UC/19-2A well, but is rare:

Umbellasphaeridium saharicum Jardiné et al.

The following species are restricted to SE/10-1 well:

?Leiofusa sp. 2

Forma H

The following species are restricted to A-1 well:

Leiofusa fastidiona Cramer

Forma G

Spore Distribution and Comparison

Spores dominate the microfossil assemblage in all the three wells studied. The spores are very varied and are represented by pseudosaccate types, sculptured types which include grana, coni, spines, ba-

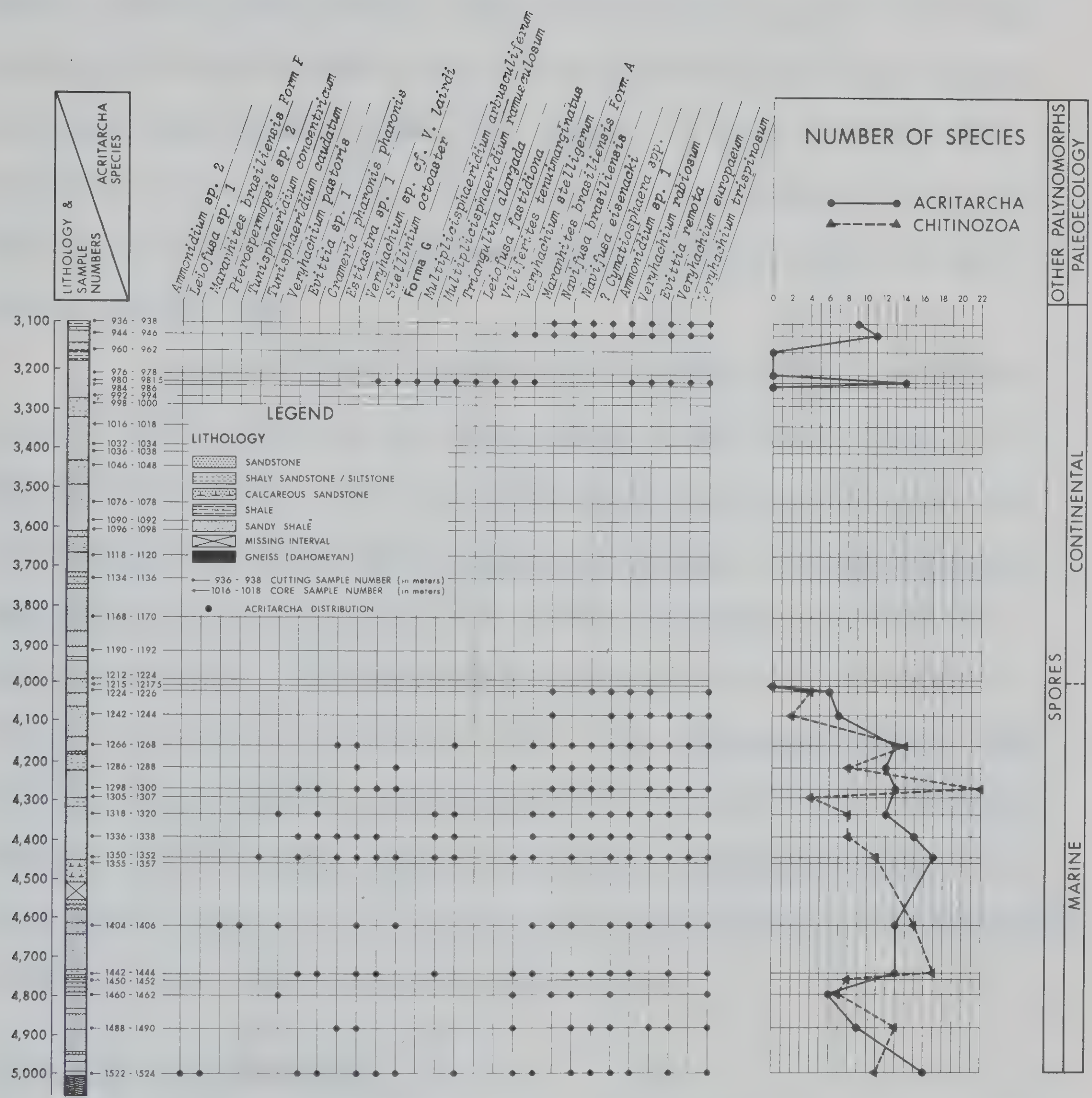

Figure 11. Range Chart of the Acritarcha Species from the Atiavi-1 Well, General Distribution of Spores, Relationships of Association between Observed Number of Chitinozoa Species and Acritarcha Species, and Summary of Paleoecology.

culae, muri (on both distal and proximal poles, or restricted to distal pole), and forms with biform, spine-like processes, spores with ribbed structures on the proximal pole, and unsculptured types which include laevigate, and retusoid forms. The amount of spore diversity and abundance increases eastward, i.e., the spore assemblage is relatively poor in the SE/10-1 well in the west, good in UC/19-1 well, and excellent in the A-1 well.

Distinct spore zonation occurs in both wells. In the continental facies overlying the marine facies in both wells (Figs. 9, 10, 11) sculptured spores, such as Reticulatisporites, Convolutispora, Converrucosisporites, Raistrickia, Archaeozonotriletes, Stenozonotriletes, Ancyrospora, Hystricosporites, and various densospores dominate the spore assemblage. The pseudosaccates are very rare in the above sections. In the marine sections of both wells, Hymenozonotriletes, Grandispora, Calyptosporites, Auroraspora occur in association with Emphanisporites, Retusotriletes, Apiculiretusispora, Spinozonotriletes, Apiculatispora, Edosporites, Biharisporites, Samarisporites, Corystisporites, Rhabdosporites, Leiotriletes and various others.

Tasmanites and Leiospheres

These microfossils occur commonly to abundantly in the marine sections of both wells. This group is particularly abundant in the lower section of the SE/10-1 well. Tasmanites and Leiospheres appear to have little stratigraphic value.

Scolecodonts

Scolecodonts occur commonly in the marine sections of both

WELL NUMBER / ACRITARCHA SPECIES	SIGNAL EXPLORATION AND DEVELOPMENT COMPANY GHANA 10-1 WELL	UNION CARBIDE GHANA 19-2A WELL	ATIAVI-1 WELL
Ammonidium sp.1	+	+	+
Ammonidium sp. 2	+	+	+
Ammonidium sp.3		+	
Crameria pharoanis pharoanis (Deunff) Jardiné et al.	+		+
Evittia granulatispinosa (Downie)Lister	+	+	
Evittia remota (Deunff)Lister	+	+	+
Evittia sp. 1	+	+	+
? Evittia sp.2		+	
Micrhystridium stellatum Deflandre	+	+	+
Multiplicisphaeridium ramusculosum (Defl.)Lister	+	+	+
Multiplicisphaeridium arbusculiferum (Downie)Staplin et al.	+	+	+
Veryhachium trispinosum (Eis.)Cramer	+	+	+
Veryhachium europaeum (Stock. & Will.)Cramer	+	+	+
Veryhachium stelligerum Deflandre	+	+	+
Veryhachium lairdi (Defl.)Deunff	+	+	+
Veryhachium sp. cf. V. lairdi (Defl.)Deunff	+	+	+
Veryhachium pastoris Deunff	+	+	+
Veryhachium rabiosum Cramer	+	+	+
Estiastra sp. 1	+	+	+
Stellinium octoaster (Staplin)Jardiné et al.	+	+	+
Pterospermopsis sp. 1	+	+	+
Pterospermopsis sp.2		+	+
Viliferites tenuimarginatus Brito	+	+	+
? Cymatiosphaera spp.	+	+	+
Leiofusa sp.1	+	+	+
? Leiofusa sp.2	+		
Navifusa brasiliensis (Brito & Santoa)Combaz et al.	+	+	+
Navifusa eisenacki (Brito & Santos)Combaz et al.	+	+	+
Maranhites brasiliensis Form A (Brito)Daemon et al.	+	+	+
Maranhites brasiliensis Form P (Brito)Daemon et al.	+	+	+
Triangulina alargada Cramer	+	+	+
Tunisphaeridium caudatum Deunff & Evitt	+	+	+
Tunisphaeridium concentricum Deunff & Evitt	+	+	+
Umbellisphaeridium saharicum Jardiné et al.	+		
Umbellisphaeridium sp. cf. U. saharicum Jardiné et al.	+	+	
Forma G			+
Forma H	+		

Table 3. Comparative Distribution of the Acritarcha Species from the Various Wells Studied.

wells. Their distribution in various horizons of the wells appears sporadic. This group occurs more commonly in the UC/19-2A well and the A-1 well to the east.

CHAPTER V

CHITINOZOA: ZONATION, CORRELATION, AND AGE

Provisional Chitinozoan Zonation and Correlation

The importance of the Chitinozoa for biostratigraphic studies has been recognised only within the last few years. In my attempt to use this group of microfossils for subdividing Devonian sediments on the shelf and coastal region of Ghana two major problems have been encountered: (a) overlaps occur in the ranges of several of the species from various wells, (b) regional differences occur in the stratigraphic range of each of several widely known Chitinozoa species which were also observed in Ghana but were not necessarily coincident with those of Brazil and elsewhere.

The most diagnostic and the most abundant chitinozoans observed from the wells are similar, however, Chitinozoa zonation is not readily apparent in any of the wells, several overlaps occur in the ranges of diagnostic species. In addition to this problem, there is distinct variation in the number of diagnostic species observed from the various wells. For example, *Angochitina* (*Ramochitina*) *ramosi* Sommer and van Boekel occurs more commonly in the A-1 well in the east part of Ghana than in the SE/10-1 well in the west; *Spaerochitina pilosa* Collinson and Scott and *Sphaerochitina schwalbi* Collinson and Scott occur at higher interval in the SE/10-1 well in the west than in the UC/19-2A well and A-1 well in the east.

Apart from these local anomalies in the distribution of the Chitinozoa, regional differences in stratigraphic ranges of various

species of Chitinozoa are common. For example, Angochitina mourai Lange which forms an important component of the Ghanaian Chitinozoa assemblage is restricted to the Upper Devonian (Frasnian) in the Paraná Basin, Brazil (Lange, 1967), whereas in the Amazon Basin, Brazil, the same species occurs in the Upper and Middle Devonian (Lange, 1967), as well as in the Lower Silurian (Costa, 1971). Angochitina (Ramochitina) magnifica Lange is restricted to the Lower Devonian in Brazil (Lange, op cit.; Costa, op cit.), yet the species was observed associated with distinctive Middle Devonian elements in Ghana. Ancyrochitina striata Taugourdeau which occurs commonly in Ghana is restricted to the Upper Devonian (Famennian) in the Sahara, North Africa (Taugourdeau, 1963) but the same species has been observed from the Middle Devonian in Brazil (Costa, 1971). Examples of different stratigraphic ranges of several species of Chitinozoa are numerous in the Devonian of North Africa, North America and South America (see Table 4).

The variation in the local distribution of some chitinozoans observed in Ghana may be related to local ecologic control of the organisms or water-mass effect. A death assemblage of organisms (thanotocoenosis) as components of sediments are distributed according to basin topography and current patterns, as such, the concentration of a particular fossil group in different parts of a basin may not necessarily reflect ecologic control of the organisms. The poor quality of samples (cutting samples) which were used in this project may have to a large extent, obscured the ranges of the various chitinozoan species.

Because of the above problems in Chitinozoa biostratigraphy, Chitinozoa zonation and correlation based on assemblages appear more meaningful and practical than paying too close attention to diagnostic

species ranges in localized areas. This approach has been followed in this work.

On the basis of the overall distribution pattern of the Chitinozoa in the various wells studies, four tentative "Chitinozoa Assemblage Zones" have been proposed for the Devonian sediments on the shelf and coastal region of Ghana as follows (in descending order):

"Zone D": Angochitina mourai Assemblage Zone

"Zone C": Angochitina devonica-Angochitina (Ramochitina) ramosi Assemblage Zone

"Zone B": Cladochitina varispinosa Assemblage Zone

"Zone A": Ancyrochitina sp. 6 Assemblage Zone

Because of the problems in the variation in the distribution of some chitinozoan species in the various wells, and overlap in the ranges of several chitinozoan species, the zones west of the UC/19-2A well are described as "Western Chitinozoa Assemblage Zones" defined by the Chitinozoa assemblage in the SE/10-1 well, and the zones east of the UC/19-2A well are described as "Eastern Chitinozoa Assemblage Zones" defined by the Chitinozoa assemblage in the A-1 well. The purpose of this is to establish a biostratigraphic framework which can be readily applied to wells in specific areas onshore and offshore Ghana.

"Zone D": Angochitina mourai Assemblage Zone

This zone is characterized by the occurrence of Angochitina mourai in association with other chitinozoan species in the various wells. Angochitina mourai, however, occurs in the lower zones in the wells, some of which may represent downhole cuttings contamination.

The upper limit of the zone is the first entry (into the drilling samples) of A. mourai which also marks the upper boundary of the distinct marine sediments in the wells. The lower limit of the zone used for this thesis is the first entry of Ancyrochitina spp.

In the SE/10-1 well ("Western Chitinozoa Assemblage Zones"), Zone D is characterized by the following Chitinozoan species:

Angochitina mourai Lange
Angochitina sp. cf. A. crumena Taugourdeau
Angochitina sp. cf. A. comosa Taugourdeau and Jekhowsky
Angochitina comosa Taugourdeau and Jekhowsky
Angochitina sp. 2
Lagenochitina amottensis Grignani and Mantovani
Sphaerochitina brevispinosa Grignani and Mantovani

These species were recovered from a sandy interval underlying the uppermost marine shaly section. A few specimens of the species were also observed between 8,100-8,150 feet depth. The lower limit of Zone D is at 8,220 feet depth which marks the entry of Ancyrochitina spp.

In the UC/19-2A well, some poorly preserved specimens of A. mourai were found between 8,000-8,260 feet depth of the well. One specimen of Chitinozoan type A was observed within the above interval and some specimens of Angochitina devonica were also found in the basal part of the zone. The first entry of Ancyrochitina spp. is at 8,260 feet depth which marks the lower limit of Zone D.

In the A-1 well ("Eastern Chitinozoa Assemblage Zones") the first entry of A. mourai is at 4,000 feet depth in the well associated with Chitinozoan type E and an abundant spore assemblage. At 4,030 feet in the well, however, the following species occur:

Angochitina mourai Lange

Hoegisphaera glabra Staplin

Lagenochitina sp. 2

Chitinozoan type E

These species occur at lower horizons as well but the first entry of *Ancyrochitina* spp. is at 4,160 feet deep which marks the lower boundary of Zone D.

"Zone C": Angochitina devonica-Angochitina (Ramochitina) ramosi Assemblage Zone

This zone carried most of the chitinozoan species which occur commonly in all the three wells but most of which are also "long-ranging". The zone is very well defined in all the three wells. The following species are characteristic of the zone and are present in all the wells:

Angochitina devonica Eisenack

Angochitina (*Ramochitina*) *ramosi* (Sommer and van Boekel)

Ancyrochitina sp. cf. *A. ancyrea* Eisenack

Ancyrochitina striata Taugourdeau

Ancyrochitina tomentosa Taugourdeau and Jekhowsky

Ancyrochitina langei Sommer and van Boekel

Ancyrochitina sp. cf. *A.* sp. Jansonius

Ancyrochitina sp. cf. *A. cornigera* Collinson and Scott

Ancyrochitina sp. 1

Ancyrochitina sp. 2

Ancyrochitina sp. 3

?*Ancyrochitina* sp. 4

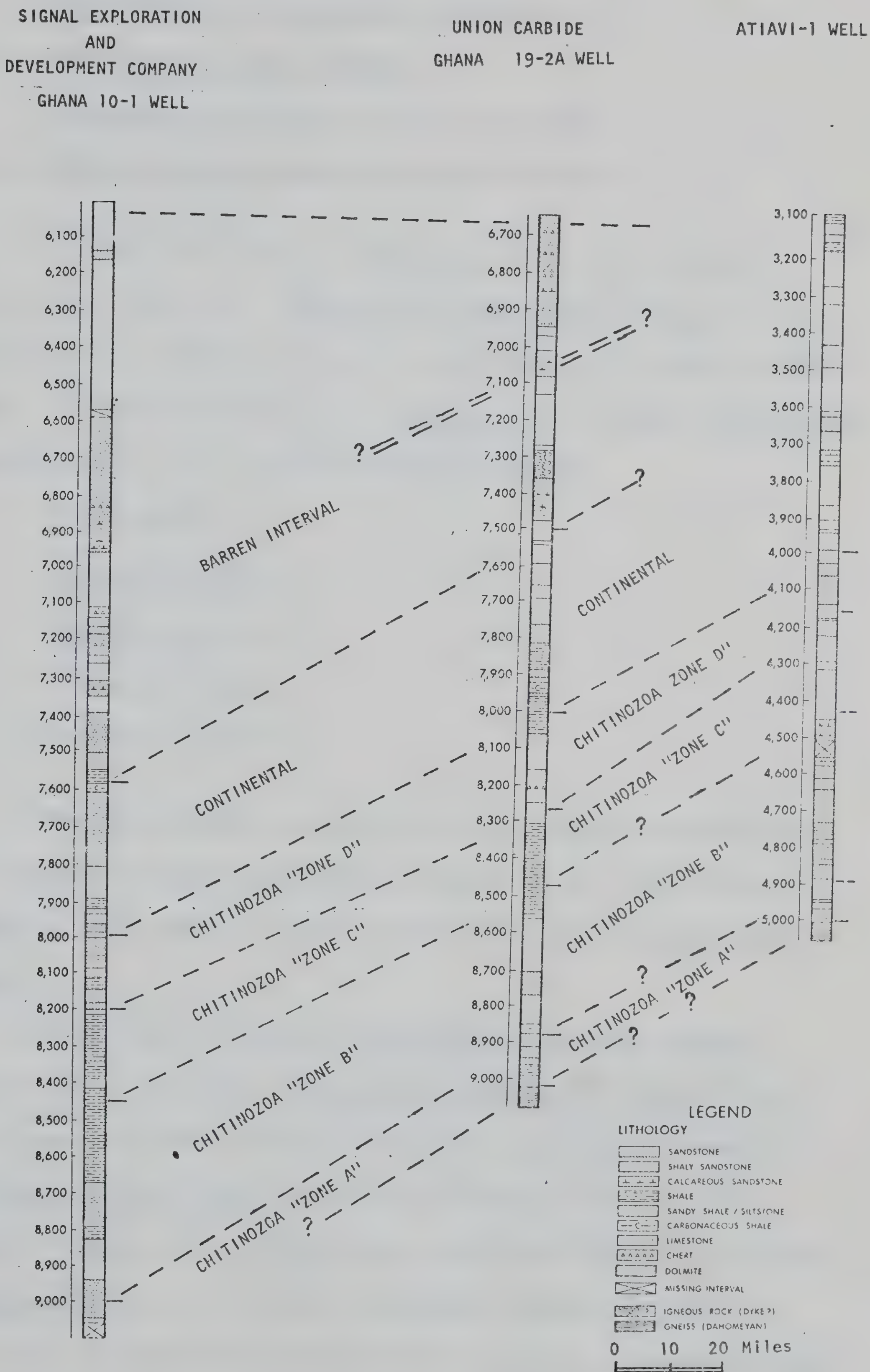

Figure 12. Chitinozoan Zonation and Correlation.

Alpenachitina eisenacki Dunn and Miller

Hoegisphaera glabra Staplin

Sphaerochitina pilosa Collinson and Scott

Sphaerochitina schwalbi Collinson and Scott

In the SE/10-1 well, A. devonica occurs more frequently than in the other two wells. Angochitina (Ramochitina) ramosi is very rare with only a few specimens observed at the base of the zone at 8,450 feet depth. A large population of A. devonica occurs between 8,300-8,500 feet associated with the following Chitinozoa species:

Sphaerochitina sp. 1

Sphaerochitina sp. 2

Sphaerochitina sp. 3

Chitinozoan type A

Chitinozoan type B

The above species, except for S. sp. 1 occur restricted to the upper section of Zone C at 8,220-8,300 feet depth. The lower limit of the zone at 8,500 feet is marked by the first entry of Cladochitina varispinosa.

In the UC/19-2A well, A. devonica was observed between 8,230-8,500 feet in the well. Angochitina (Ramochitina) ramosi occurs restricted between 8,290-8,500 feet. With the exception of a few species of Ancyrochitina striata at the base of the well at 9,010 feet, most of the specimens of A. striata occur restricted between 8,250-8,400 feet. Ancyrochitina sp. cf. A. sp. Jansonius is better developed in this well than the two other wells with the occurrence restricted between 8,280-8,400 feet depth. The lower limit of Zone C is at 8,500 feet depth

marked by the disappearance of Angochitina (Ramochitina) ramosi and the first entry of Cladochitina varispinosa.

In the A-1 well, the first entries of Angochitina devonica and Angochitina (Ramochitina) ramosi is at about 4,160 feet depth. Angochitina (Ramochitina) ramosi is better developed in this well than in the two other wells with the occurrence extending to the base of the well. This species occurs abundantly at about 4,265 feet depth. Angochitina devonica is better developed at a lower horizon in Zone B in the well. However, some varieties of A. devonica (Angochitina sp. cf. A. devonica) occur restricted to the upper limit of Zone C. The most diagnostic species of this zone is Angochitina callawayensis restricted to between 4,160-4,275 feet depth in the well. Ancyrochitina striata also occurs commonly in this zone at 4,160 feet. This zone also carries Cladochitina varispinosa which is very diagnostic of Zone B in the UC/19-2A well. The lower limit of Zone C of A-1 well is subjective, but is placed just above 4,470 feet in the well by the first entry of Sphaerochitina sp. 1 which is one of the most diagnostic species in Zone B in both UC/19-2A well and SE/10-1 well.

"Zone B": Cladochitina varispinosa Assemblage Zone

This zone contains most of the species observed in Zone C. The upper limit of the zone is marked by the first entry of Cladochitina varispinosa at 8,500 feet in UC/19-2A well and at the same depth of 8,500 feet in SE/10-1 well in the west. As indicated previously, this species was observed at higher levels in Zone C in A-1 well in the east.

In the "Western Chitinozoa Assemblage Zone", Zone B is characterized by the following species together with most of the species listed in Zone C, as follows:

Ancyrochitina sp. cf. *A. desmea* Eisenack

Ancyrochitina tumida Taugourdeau and Jekhowsky

Ancyrochitina sp. 5

Ancyrochitina sp. 7

Angochitina sp. 1

Angochitina (*Ramochitina*) *magnifica* (Lange)

Angochitina sp. cf. *A. longicolla* Eisenack

Fungochitina sp. cf. *A. pistilliformis lata* Taugourdeau and Jekhowsky

Rhabdochitina sp. cf. *R. magna* Eisenack

Sphaerochitina sp. 1

Chitinozoan type C

Several of the above species are, however, rare in the zone with only one or a few specimens observed. *Cladochitina varispinosa* was also observed at the base of the well at 9,050 feet depth. The lower limit of Zone B in SE/10-1 well was put at 9,000 feet in the well by the significant occurrence of *Ancyrochitina* sp. 6. A single specimen of this species was, however, observed in Zone C at 8,450 feet in the well.

In the UC/19-2A well, *Cladochitina varispinosa* is very abundant. Like the occurrence of this species in the SE/10-1 well, this species was also found in the lower section of the UC/19-2A well. *Sphaerochitina pilosa*, *Sphaerochitina schwalbi*, and *Sphaerochitina* sp. 1 are very well developed in this zone, though they occur commonly in Zone C of SE/10-1 well to the west. Zone B of UC/19-2A well has in com-

CHITINOZOA SPECIES / WEST AFRICA Ghana: This Thesis	NORTH AFRICA Sahara: Taugourdeau & Jekhowsky (1960); Taugourdeau (1962; 1963; 1966) Morocco: Grignani & Mantovani (1964)	SOUTH AMERICA Brazil; Lange (1949, 1952, 1967); Sommer & van Boekel (1965); da Costa (1966, 1968, 1971).	NORTH AMERICA Illinois: Collinson & Schwalb (1955); Collinson & Scott (1958); Iowa: Dunn (1959); Urban (1972) Missouri: Urban & Kline (1970) Souththern Ontario: Legault (1971, Unpl. Ph.D. Thesis) Other Localities: Staplin (1961); Dunn & Miller (1964); Jansonius (1967)
Alpenachitina eisenacki Dunn & Miller	MD	MD	MD
Ancyrochitina sp. cf. A. ancyrea Eisenack	S;LD;MD	LD;MD	
Ancyrochitina striata Taugourdeau	UD	MD	
Ancyrochitina langei Sommer & van Boekel		MD	MD
Ancyrochitina sp. cf. A. cornigera Coll. & Scott		MD	MD
Ancyrochitina sp. cf. A. gumersinda Cramer			
Ancyrochitina tomentosa Taug. & Jekh.	LS;MD;UD		MD
Ancyrochitina sp. cf. A. spinosa Eisenack	MD;UD	LD	MD
Ancyrochitina sp. cf. A. desmea Eisenack		MD	MD
Ancyrochitina tumida Taug. & Jekh.	LD;MD;UD	MD	MD
Ancyrochitina sp. cf. A. sp. Jansonius			UD
? *Ancyrochitina sp. cf. A. aequoris* Urban & Kline			MD
Angochitina devonica Eisenack	LD;MD;UD	LD;MD	MD
Angochitina callawayensis Urban & Kline			MD
Angochitina sp. cf. A. capillata Eisenack	UD	LD;MD;UD	MD
Angochitina mourai Lange	UD	LS;MD;UD	MD
Angochitina (Ramochitina) ramosi Sommer & van Boekel		LD;MD	
Angochitina (Ramochitina) magnifica Lange		LD	
Angochitina comosa Taug. & Jekh.	LD;UD		
Angochitina sp. cf. A. crumena Taugourdeau	LD;UD	LS	
Angochitinasp. cf. A. bifurcata Coll. & Schwalb		MD	LD
Angochitina sp. cf. A. longicolla Eisenack	S		
Cladochitina varispinosa Lange		MD	
Fungochitina sp. cf. F. pistillifopmis lata Taug. & Jekh.	S;LD;MD;UD		
Fungochitina longicollis Taug. & Jekh.	LD		
Hoegisphaera glabra Staplin			MD;UD
Lagenochitina amottensis Grig. & Mantovani	MD;UD		MD
Sphaerochitina pilosa Coll. & Scott	S;UD		MD
Sphaerochitina schwalbi Coll. & Scott			MD
Sphaerochitina sp. cf. S. brevispinosa Grig. & Mantovani	MD;UD		
Sphaerochitina sphaerocephala Eisenack	MD;UD	LS	
Sphaerochitina sp. cf. S. cuvillieri Taugourdeau	UD	LD;MD	
Urochitina sp. cf. U. bastosi van Boekel		MD	

Table 4. Comparative Distribution and Age of the Chitinozoa Species from Ghana Conspecific with or similar to Recorded Forms in Various Chitinozoa Assemblage Suites. (Symbols: LS - Lower Silurian; S - Silurian; LD - Lower Devonian; MD - Middle Devonian; UD - Upper Devonian). Note: *Ancyrochitina gumersinda* Cramer described from Emsian, NW Spain, Cramer (1964).

mon with Zone B of SE/10-1 well, Ancyrochitina sp. 5, and Angochitina sp. 1 which are absent in A-1 well in the east. The lower limit of Zone B in UC/19-2A well is put at the first entry of Ancyrochitina sp. 6 at 8,880 feet depth.

In A-1 well, Zone B is poorly defined, since the diagnostic species, Cladochitina varispinosa was observed at higher horizon in Zone C. However, like UC/19-2A well, Sphaerochitina pilosa and Sphaerochitina schwalbi are well represented in this zone. Zone B of A-1 well further correlates with SE/10-1 well through the occurrence of Ancyrochitina sp. cf. A. desmea in the zone. New entries of diagnostic chitinozoan species in this zone are as follows:

?Ancyrochitina sp. cf. A. aequoris Urban and Kline

?Conochitina sp. 5

Chitinozoan type B

The lower limit of this zone in this well was tentatively put at about 4,900 feet depth in the well.

"Zone A": Ancyrochitina sp. 6 Assemblage Zone

This zone is distinctive in UC/19-2A well but lacks definition westward in SE/10-1 well and eastward in A-1 well. Several of the chitinozoan species which occur at higher horizons were also observed in this zone.

In the SE/10-1 well, the only new entry is Chitinozoan type D associated with "long-ranging" species.

In the UC/19-2A well, Ancyrochitina sp, 6 occurs commonly in association with Ancyrochitina sp. cf. A. gumersinda, and "long-ranging" species. The following new entries are restricted at the base of the well but are very rare with only single specimens observed:

Fungochitina longicollis Taugourdeau and Jekhowsky

Rhabdochitina sp. 1

In A-1 well only two specimens of *Ancyrochitina* sp. 6 were observed with one of the specimens occurring within Zone B at about 4,750 feet depth and the other at the base of the well at 5,000 feet. The only new entry is Chitinozoan type C which occurs at the base of the well. ?*Ancyrochitina* sp. cf. *A. aequoris* occurs abundantly at the base of the well together with other "long-ranging" species.

Chitinozoa zonation and correlation of the three wells studied is indicated in Figure 12.

Regional Chitinozoan Correlation and Age

Thirty-four of the 68 Chitinozoa species observed from Ghana, West Africa are conspecific with or similar to several Chitinozoa species described or reported from various localities in Europe, North Africa, South America, and North America. Characteristics in similarities or variation of the Ghanaian specimens with specimens from various localities are discussed in the Systematic Descriptions in Chapter Nine.

On broad stratigraphic ranges of these species, 4 are long-ranging and have been reported from the Ordovician, Silurian, and Devonian; 12 from the Silurian to Devonian; and 18 appear to be restricted to the Devonian.

The following species have been recorded from Ordovician, Silurian and Devonian sediments:

Ancyrochitina sp. cf. *A. ancyrea* Eisenack

Angochitina sp. cf. *A. capillata* Eisenack

Hoegisphaera glabra Staplin

Rhabdochitina sp. cf. *R. magna* Eisenack

Ancyrochitina sp. cf. A. ancyrea A. sp. cf. A. capillata, and H. glabra form important components in the Ghanaian assemblage. Only a single specimen of R. sp. cf. R. magna was observed.

The following species have been reported from the Silurian and Devonian:

Ancyrochitina tomentosa Taugourdeau and Jekhowsky
Ancyrochitina tumida Taugourdeau and Jekhowsky
Ancyrochitina sp. cf. A. desmea Eisenack
Angochitina devonica Eisenack
Angochitina mourai Lange
Angochitina sp. cf. A. crumena Taugourdeau
Angochitina sp. cf. A. longicolla Eisenack
Fungochitina sp. cf. F. pistilliformis lata Taugourdeau and Jekowsky
Sphaerochitina sphaerocephala Eisenack
Sphaerochitina pilosa Collinson and Scott
Rhabdochitina sp. cf. R. claviformis Taugourdeau

With the exception of F. sp. cf. F. pistilliformis lata, A. longicolla, and R. sp. cf. R. claviformis, of which single specimens were observed, the rest of the species occur fairly commonly to abundantly in the Ghanaian chitinozoan assemblage.

The following species have been reported only from the Lower Devonian:

Ancyrochitina sp. cf. A. gumersinda Cramer
Angochitina (Ramochitina) magnifica (Lange)
Fungochitina longicollis Taugourdeau and Jekhowsky. Ancyrochitina sp. cf. A. gumersinda occurs fairly commonly but only single specimens of A.(R). magnifica, and F. longicollis were observed.

The following species have been recorded from the Lower and Middle Devonian:

Angochitina sp. cf. *A. bifurcata* Collinson and Schwalb

Angochitina (*Ramochitina*) *ramosi* (Sommer and van Boekel)

Angochitina (*Ramochitina*) *ramosi* occurs commonly to abundantly in the various wells, *A.* sp. cf. *A. bifurcata* is generally rare.

The following species have been reported from the Lower to Upper Devonian:

Angochitina comosa Taugourdeau and Jekhowsky

Sphaerochitina sp. cf. *S. cuvillieri* Taugourdeau

Only a few specimens of these species were observed from Ghana.

The following species are restricted to the Middle Devonian:

Alpenachitina eisenacki Dunn and Miller

Ancyrochitina sp. cf. *A. cornigera* Collinson and Scott

Ancyrochitina langei Sommer and van Boekel

?*Ancyrochitina* sp. cf. *A. aequoris* Urban and Kline

Angochitina callawayensis Urban and Kline

Cladochitina varispinosa Lange

Sphaerochitina schwalbi Collinson and Scott

Urochitina sp. cf. *U. bastosi* van Boekel

All the above species, except *U.* sp. cf. *U. bastosi* occur commonly to abundantly in the Ghanaian assemblage.

The following species have been reported from the Middle and/or Upper Devonian:

Ancyrochitina striata Taugourdeau

Ancyrochitina sp. cf. A. sp. Jansonius

Lagenochitina amottensis Grignani and Mantovani

Sphaerochitina brevispinosa Grignani and Mantovani

Ancyrochitina striata and A. sp. cf. A. sp. Jansonius occur commonly to abundantly; L. amottensis and S. sp. cf. S. brevispinosa are rare.

Table 4 is a summary of comparative distribution and age of the chitinozoan species which occur common to Ghana and various chitinozoan assemblage suites in North Africa, South America, and North America. The chitinozoan assemblages from these regions are more closely related to the Ghanaian assemblage, and almost all the species have been reported from the Devonian. As an attempt to suggest a more specific age for the Ghanaian chitinozoan assemblage, the distribution of some of the most diagnostic chitinozoan species in the various "zones" proposed for the wells are discussed.

Ancyrochitina tomentosa occurs in Zones A, B, and C of all the wells, except in the A-1 well in which the species was not observed from the lower section of the well. This species has been described from the Lower Silurian to Middle Devonian in the Sahara (Taugourdeau and Jekhowsky, 1960). The species has also been reported from the Lower Devonian in the Moesian Platform, Romania (Beju, 1967). In Zone A of the UC/19-2A well, Ancyrochitina sp. cf. A. gumersinda described from the Lower Devonian of NW Spain (Cramer, 1964), occurs commonly. Angochitina (Ramochitina) ramosi occurs commonly to abundantly in the A-1 well ranging from Zone C to Zone A of the well. This species is diagnostic of the Lower to Middle Devonian of Brazil (Sommer and van Boekel, 1965; Lange, 1967; Costa, 1971). In the SE/10-1 well, a single specimen

of another diagnostic Brazilian species restricted to the Lower Devonian--Angochitina (Ramochitina) magnifica (Lange, op. cit.; Costa, op. cit.) was observed in Zone C of the well. According to the Ghana Geological Survey (pers. comm.) the total depth of the SE/10-1 well was 9,735 feet but the lower 670 feet of the samples from the well were not accounted for by the company which drilled the well. Because of this, the samples from the lower sections of the wells adjacent to SE/10-1 well, i.e. SE/10-1 well and SE/13-2 well (Fig. 5) were processed to check on the chitinozoan assemblages. The chitinozoan assemblages from the lower sections of these two wells are closely similar to Zone A assemblage of the SE/10-1 well containing several Ancyrochitina tomentosa. Three specimens of Sphaerochitina lucianoi described from the Lower Devonian of the Amazon Basin, Brazil by Sommer and van Boekel (1965) were observed from the interval 9,450-9,550 feet deep of the SE/13-2 well. On the basis of occurrences of Lower Devonian Chitinozoa species in Zone A of the three wells studied, a Lower Devonian age is proposed for Zone A of the Chitinozoa assemblage zones in Ghana.

Zone B and Zone C of the various wells studied carry several distinctive Middle Devonian chitinozoan species, as listed previously, which have been reported from the Sahara (Taugourdeau and Jekhowsky, 1960; Taugourdeau, 1962, 1963, 1966), Morocco (Grignani and Mantovani, 1964), Paraná, Amazon and Maranhao basins in Brazil (Lange, 1949, 1952, 1967; Sommer and van Boekel, 1965; da Costa, 1966, 1968, 1971) and various Middle Devonian Formations in North America, i.e., Middle Devonian Cedar Valley Formation in Illinois (Collinson and Scott, 1958), Middle Devonian Cedar Valley Formation in Iowa (Dunn, 1959; Urban, 1972), Middle Devonian Cedar City Formation in Missouri (Urban and Kline, 1970),

and Middle Devonian (Givetian) Hamilton Group in southern Ontario (Legault, 1971, Unpubl. Ph. D. Thesis, Univ. Oklahoma). Both Eifelian and Givetian elements are represented in Zones B and C.

The distinctive character of Zone D of both wells is the dominance of Angochitina mourai. Ancyrochitina spp. are absent in the zone. According to Lange (1967), a few specimens of A. mourai occur in the Middle Devonian Ereré Formation in the Amazon basin, but in the Curuá Formation the species is restricted to the Upper Devonian (Frasnian). The species has also been reported restricted to the same stratigraphic interval (Frasnian) in the Paraná basin, Brazil (Lange, op cit.), Frasnian in Bolivia (Cousminer, 1964 in Lange op cit.), and the Upper Devonian in Morocco (Grignani and Mantovani, 1964). Collinson and Scott (1958) reported the species from the Middle Devonian Cedar Valley Formation in Illinois. According to Costa (1971) the stratigraphic range of the species is Silurian to Upper Devonian in Brazil, thus its occurrences in lower horizons in Ghana is not unexpected. Significantly, in the SE/10-1 well A. mourai occurs in Zone A associated with A. comosa, A. sp. cf. A. crumena, L. amottensis, S. sp. cf. S. brevispinosa, and S. sp. cf. S. cuvillieri. All the listed species have been reported from the Upper Devonian in Morocco (Grignani and Mantovani op cit.). Furthermore, in the upper sections of Zone C of both UC/19-2A well and A-1 well, A. striata occurs most commonly. This species was reported restricted to the Famennian in the Sahara (Taugourdeau, 1963) though it has also been reported from the Middle Devonian in Brazil (Costa, 1971). Ancyrochitina sp. cf. A. sp. Jansonius described by Jansonius (1967) from the Upper Devonian (Frasnian), Hay River, Northwest Territories, Canada occurs very commonly, particularly in the upper

ACRITARCHA SPECIES / WEST AFRICA — Ghana: This Thesis	NORTH AFRICA — Tunisia: Deunff (1966); Deunff and Evitt (1968); Sahara: Jardine and Yapaudjian (1968); Magloire (1968); Lanzoni and Magloire (1969); Jardiné et al. (1972)	SOUTH AMERICA — Brazil: Brito, (1965; 1967); Lauge (1967); Daemon et al. (1967)	NORTH AMERICA — Canada: Staplin (1961); Deunff (1955, 1967); Lagault (1971, Unpub. Ph. D. Thesis); New York: Deunff and Evitt (1968)
Crameria pharonis pharonis (Deunff) Jardiné et al.	LD; MD; UD		
Evittia granulatispinosa (Downie) Lister	LD; MD	LD; MD	D
Evittia remota (Deunff) Lister	LD; MD	LD; MD	D
Multiplicisphaeridium ramusculosum (Defl.) Lister	S; LD		D
Multiplicisphaeridium arbusculiferum (Downie) Staplin et al.	S; LD		UD
Stellinium octoaster (Staplin) Jardiné et al.	MD; UD		UD
Veliferites tenuimarginatus Brito		LD; MD	
Navifusa brasiliensis (Brito & Santos) Combaz et al.	MD	MD: UD	
Navifusa eisenacki (Brito & Santos) Combaz et al.		MD; UD	
Maranhites brasiliensis Form A (Brito) Daemon et al.	UD	MD; UD	
Maranhites brasiliensis Form P (Brito) Daemon et al.	UD	MD; UD	
Triangulina alargada Cramer	LD	LD; MD	MD
Tunisphaeridium caudatum Deunff & Evitt	LD		S
Tunisphaeridium concentricum Deunff & Evitt			S; MD
Umbellisphaeridium saharicum Jardiné et al.	UD	MD	

Table 5. Comparative Distribution and Age of the Acritarcha from Ghana Conspecific with or Similar to Recorded Forms in Various Acritarcha Assemblage Suites. (Symbols: S-Silurian; LD-Lower Devonian; MD-Middle Devonian; UD-Upper Devonian).

section of Zone C of UC/19-2A well. Since diagnostic Middle Devonian chitinozoan species appear to be absent from Zone A of the Chitinozoa Assemblage Zones in Ghana, an Upper Devonian age, probably Frasnian, is suggested for Zone D and possibly the upper section of Zone C.

In the UC/19-2A well, some chitinozoan species were observed from a thin calcareous sandy shales at 7,060 feet located within a barren interval. These species were not observed from the distinct marine section of the well and it appears unlikely that they were reworked. The occurrence of chitinozoans nearer to the upper limit of the Paleozoic sediments from the well appears to delimit the sediments to pre-Carboniferous age.

Relations of the Chitinozoa to the Acritarcha and Spores

Of a total of 37 acritarch species observed from Ghana, 24 have been reported from several Silurian and Devonian formations in Europe, North Africa, South America and North America. Several of these species range from Zone D to Zone A of the Chitinozoa Assemblage Zones in Ghana with a significant number of them occurring also in the terminal acritarch "zones" of the wells which mark the upper boundary of Paleozoic sediments (Figs. 9, 10, 11). Acritarch zonation is not apparent in any of the wells studied.

The most diagnostic of the acritarch species which were observed from Ghana and have been reported from various localities are as follows:

Crameria pharoanis pharoanis (Deunff) Jardine *et al*. This species occurs commonly in the SE/10-1 well and the A-1 well. The species has been reported from the Emsian to Frasnian or base Eifelian to Fras-

nian in the Sahara (Jardine et al., 1972). Crameria pharoanis (Deunff) Lister has previously been recorded from various Devonian sediments, e.g: Hamilton Group Canada (Deunff, 1955); Frasnian in Belgium (Stockmans and Willière, 1962); Emsian to Frasnian in the Sahara (Jardine et al., 1972).

Evittia granulatispinosa (Downie) Lister occurs commonly in the UC/19-2A well and A-1 well. This species has been reported from the Wenlock, Shropshire, England (Downie, 1963); Wenlock and Ludlow Series, Shropshire (Lister, 1970); Silurian to Devonian in the Plourach Region, North Coast (Deunff and Paris, 1972).

Evittia remota (Deunff) Lister is one of the dominant components of the acritarch assemblage in the wells studied. The species has been reported from various Paleozoic sediments as follows: Devonian of Canada (Deunff, 1955, 1966); Middle Devonian of Tunisia (Deunff, 1966); Siegenian to Emsian, NW Spain (Cramer, 1964); Early to Middle Devonian of Brazil (Brito, 1965); Emsian to Givetian, Algeria (Jardine and Yapaudjian, 1968); Lower Devonian of the Moesian Platform, Romania (Beju, 1967 in Lister, 1970); Wenlock to Ludlow Series, Shropshire (Lister, 1970); Emsian of the Sahara, Algeria (Jardine et al, 1972).

Multiplicisphaeridium ramusculosum (Deflandre) Lister, and Multiplicisphaeridium arbusculiferum (Downie) Staplin et al. occur commonly in the Ghanaian assemblage. Both species appear to be very cosmopolitan and have been recorded from various Silurian and Devonian sediments. Downie (1963) reported both species from the Wenlock Shales, Shropshire. Cramer (1964) recorded them from the La Vid Shale (Lower Devonian), NW Spain. The species also occurs in the Calcaire D'Angers (Emsian) (Moreau-Benoit, 1967); Lower Devonian of the Moesian Platform,

Romania (Beju, 1967); Wenlock and Ludlow Series, Shropshire (Lister, 1970).

Tunisphaeridium caudatum Deunff and Evitt, and Tunisphaeridium concentricum Deunff and Evitt which occur commonly in the Ghanaian assemblage have been recorded from the Middle Silurian of New York (Deunff and Evitt, 1968). T. caudatum also occurs in the Lower Devonian (Gedinian) of Tunisia (Deunff and Evitt, op. cit.) Legault (1971, Unpl. Ph.D. Thesis) reported T. concentricum from the Middle Devonian (Givetian) Hamilton Group of southern Ontario, Canada.

Triangulina alargada Cramer occurs sparingly in all the wells. In A-1 well this species was observed in the terminal acritarch assemblage overlying the distinct continental material of the well. T. alargada was first described from the Lower Devonian (Emsian) in NW Spain (Cramer, 1964). Brito (1967) recorded the species from the Devonian of Brazil, and Legault (op. cit.) has reported the species from the Middle Devonian (Givetian) Hamilton Group of southern Ontario, Canada.

Umbellasphaeridium saharicum described from the Upper Devonian of the Sahara by Jardiné et al. (1972) occurs sparingly in the Ghanaian assemblage.

Apart from the above listed acritarch species which occur commonly in the Ghanaian assemblage, several acritarch species which have been reported from the Lower to Upper Devonian in Brazil form very important components of the Ghanaian assemblage. These include the following:

Navifusa brasiliensis (Brito and Santos) Combaz et al.

Navifusa eisenacki (Brito and Santos) Combaz et al.

Maranhites brasiliensis Form A (Brito) Daemon et al.

Maranhites brasiliensis Form P (Brito) Daemon et al.

Comparative distribution and age of the diagnostic acritarchs species common to Ghana, West Africa, and North Africa, South America and North America is indicated in Table 5.

A detailed taxonomy of the spores which occur in the wells has not been attempted yet, but the varied spore assemblage as discussed previously suggests abundant floristic bloom during the period of the sedimentation, and this probably indicates post-Silurian age for the sediments. Casual comparison of the spore assemblage from Ghana with a Lower to Upper Devonian (Emsian-Frasnian) spore assemblage described from the Paraná basin, Brazil (Daemon _et al_., 1967), and a "probable Middle Devonian" spore assemblage described from Paraguay (Menendez and de Baldis, 1967) shows several spore species which are closely similar. Thus, both from the acritarch and spore evidences the Paleozoic sediments from the exploratory oil wells on the shelf and coastal region of Ghana suggest a Lower to Upper Devonian age. A detailed taxonomy of the spores will probably offer the best clue as to the exact age of the sediments.

CHAPTER VI

PALEOECOLOGY OF THE SEDIMENTS

Introduction

Paleoecologic interpretations of sediments based solely on the relationship of association between microfossil groups of different sizes, densities, and morphographic characters may be subjective. This is due to selective, destructive action of current, winnowing, and diagenetic processes on the various microfossil groups, as well as different degrees of preservation. The use of samples of poor quality, such as cutting samples, may add to the unreliability of paleoecologic analysis of the sediments.

The objective here is to outline briefly the main paleoenvironmental changes during the deposition of the sediments. No attempt is made to discuss in detail the various paleoecologic niches of the various microfossil groups, only a broad general outline is indicated.

Studies of the Chitinozoa from various sedimentary basins by various workers indicate that the group flourished in shallow marine waters, especially near the margins of basins during the Ordovician, Silurian and Devonian periods. Benthonic, planktonic, pseudoplanktonic mode of life, or a combination of these in one life cycle has been suggested for the group.

Jenkins (1969) has suggested that generally chitinozoan species are of wide lateral distribution and are affected relatively little by minor facies changes. According to him (Jenkins, 1970, p. 11) "...within short sequences of either mixed or uniform lithology the concentration of chitinozoans in the rock may vary greatly and capriciously, but the same species are present everywhere and the relative abundance of each species remains the same..." Similar observations have been reported for chitinozoans from the Middle Devonian Hamilton Group in southern Ontario, Canada (Legault, 1971). The writer has indicated in the preceding chapter that several species of the Chitinozoa observed in Ghana are conspecific in both wells studied which are located several miles apart. However, chitinozoan zonation is not readily apparent in any of the wells. Several species in the lower zones occur in the upper zones. Urban and Kline (1970) however, have suggested that a definite relationship exists between facies and chitinozoan distribution in Middle Devonian limestone sequences in the central United States.

The acritarchs evolved during the Precambrian and became an important group of the plankton during the lower Paleozoic, probably continuing as such until the Mesozoic (Downie, 1973). According to Downie (op. cit.), the group was probably the largest contributor to the biomass during this period, for, in marine sediments from about 1,000 to 3,000 million years old the acritarchs are found in numbers usually between 1,000 to 10,000 per gramme, provided that diagenesis, metamorphism, or abrasion has not affected them.

Apart from a few reported fresh-water acritarchs from the Late Permian of the Prince Charles Mountains in the Antarctica (Balme and

Playford, 1967), Pleistocene peats of England (Sarjeant and Strachan, 1968) and Holocene lake deposits in Australia (Harland and Sarjeant, 1970), all others have been found in marine sediments.

In marine sediments the acritarchs occur most commonly in shales but also occur in a wide variety of carbonates and arenaceous sediments. Staplin (1961) has shown that three types of acritarchs or "growth-forms" have different patterns of distribution with regard to Upper Devonian reefs in Alberta, Canada: (1) simple spherical forms occur all the way from shales interbedded with reef carbonate. Their abundance, however, increases away from the reefs, as do the numbers of species. (2) Thin-walled forms are also widespread but are seldom found within one mile of the reefs. (3) Thick-spined and polyhedral forms occur in off-reef strata.

Smith and Saunders (1969) have indicated that acritarchs are confined to depositional areas continuously or intermittently open to marine waters and do not occur in fluvial deposits. According to these workers, the degree of preservation of the acritarchs reflects the depositional environment--forms from deeper open marine sediments are generally well preserved, while those in near-shore and transitional facies are usually fragmentary and abraded. Current patterns in sedimentary basins affect the distribution of acritarchs because of their planktonic habits and microscopic size.

In the Silurian a widespread provincial distribution, possibly climatically controlled, has been determined by Cramer (1970 in Downie, 1973), affecting the continents bounding the Atlantic. Like the chitinozoans, the knowledge of the paleoecology of the acritarchs is still limited.

The scolecodonts are jaw apparatus of marine polychaete worms and their presence in sediments indicates shallow marine conditions.

The spores are continental in origin, and their distribution in marine waters depends on wind direction as well as current patterns in the basins. The extent of their diversity and abundance indicates proximity to shorelines.

On the basis of the habits and habitats of the above Paleozoic micro-organisms and their distribution in the various exploratory oil wells on the shelf and coastal region of Ghana two main paleoecologic conditions are suggested for the sediments from the wells.

Marine Conditions

The thicknesses of the marine sections in the three wells studied as well as their microfossil distributions have been discussed. The thicknesses of the marine sediments from the three wells decrease eastward, chitinozoan diversity decreases eastward, and spore diversity and abundance increases eastward. This relationship suggests that the Devonian transgression was toward the east in relation to the present magnetic pole position.

A plot of the chitinozoan diversity and the acritarch diversity at various horizons of the marine sections in both wells shows somewhat erratic patterns, but there is a general similarity between the various plots (Figs. 9, 10, 11).

Generally, species diversity for both chitinozoans and acritarchs is lower in sandy sections and higher in shaly sections. This is expected since many microfossils become abraded or winnowed out in sandy environments. A large number of abraded chitinozoans were usually

observed in the sandy sections. Since acritarchs are considerably smaller than chitinozoans they are liable to be winnowed out faster. Their low diversity in sandy sections parallels the fewer species of chitinozoans observed in sandy sections, reduced by abrasion and winnowing.

In both wells species diversity is high at the base of the marine sediments, followed by a sharp decrease, then a long period of general fluctuations, and finally a relatively slow decline. This probably indicates that the flooding of the Devonian Sea was rapid and both acritarchs and chitinozoans flourished almost immediately. The greater number of acritarch species at the base of the marine sections reflects initial shallow marine conditions. The decrease in species diversity immediately following the basal sediments and corresponding to sandy sections in the wells suggests a partial regression or discharge of a large volume of coarse clastics within the interval. Following this interval, there appears to have been a general increase in water depth accompanied by periodic fluctuations, and finally a relatively slow regression in which the chitinozoans and the acritarchs were eliminated in the UC/19-2A and the A-1 wells in the east. In the SE/10-1 well in the west, however, the acritarchs flourished for a longer period after the chitinozoans have perished. This appears to indicate that the regression of the Devonian Sea was followed by a deltaic or brackish water condition in the west. The SE/10-1 well is a proven oil-bearing well with one of the two oil zones corresponding to the terminal marine zone. The close relationship between oil generation and delta build-up is a well-known geologic phenomenon.

In the entire marine sections of the wells spores and scole-

codonts occur commonly to abundantly. The occurrence of these microfossils in association with the chitinozoans and the acritarchs in interbedded series of shales, sandy shales, siltstones, and sandstones all indicate the generally shallow conditions of the Devonian Sea.

Continental Conditions

As the spores which constitute the continental materials have not been studied in detail, no specific paleoenvironmental conditions can be suggested, but considering the generally silty nature of the sediments in which the spores accumulated, swampy tidal flats probably prevailed at the time of the deposition of the sediments.

The barren sections overlying the distinctly continental materials in the SE/10-1 and the UC/19-2A wells are probably the result of destruction of organic material and reflect continental conditions. The sediments in the barren intervals are mostly reddish brown coarse grained sandstones, siltstones, and sandy shales. Some carbonates bands occur in both wells, but samples prepared from these carbonate were barren, except for some few chitinozoans, spores, and poorly preserved acritarchs in a thin calcareous sandstone at 7,060 feet depth of UC/19-2A well. A restricted marine invasion probably occurred at this horizon. The distinct acritarch zones at the terminal portion of the Paleozoic sediments of the three wells probably indicate brackish water conditions at the end of the Devonian period.

Figure 13. The Fit of Africa and South America at the 500 fm Contour Produced by Rigid Rotation (after McKenzie, 1970).

CHAPTER VII

AN APPRAISAL OF THE GHANAIAN AND BRAZILIAN DEVONIAN CHITINOZOAN AND ACRITARCH ASSEMBLAGE SUITES

Proponents of the theory of continental drift usually refer to the jigsaw-puzzle fit of the Atlantic coasts of Africa and South America (Fig. 13) as one of the strong supporting pieces of evidence of the theory. These two continents including the island of Madagascar, India, Australia and the Antartica were supposed to have constituted the super-continent of Gondwanaland in the Paleozoic and early Mesozoic eras. Several workers have shown that the geology and paleontology of the above regions during the Paleozoic and Mesozoic eras are similar.

Recently, Hurley and others (in Hurley, 1968) indicated that the 2,000 million-year-old cratonic rocks of Ghana, the Ivory Coast and westwards from these countries, as well as the 600 million-year-old province of Dahomey, Nigeria and in the east of these countries have their equivalents in Brazil, and probably a piece of the 2,000 million-year-old craton of West Africa had been left on the continent of South America. According to these workers, the structural trends as well as the mineral characteristics of individual belts of ores, i.e., manganese, iron, gold and tin seem to follow a matching pattern where the coasts once joined.

The concept of continental drift is beyond the scope of this

project. The remarks following are essentially a brief resumé of the writer's impressions on the remarkable similarity of the Devonian microfossil assemblage suites of Ghana and Brazil.

Lithologically, the Devonian sediments in Brazil are composed of a series of sandstones, siltstones, sandy shales and shales which are occasionally micaceous. These sediments are closely similar to the Ghanaian Devonian sediments.

In comparing the Ghanaian microfossil species with similar species described from various regions, including Brazil, South America, there were some species described from Brazil which have not been recorded from other regions but most of which form important components of the Ghanaian microfossil assemblage. These have already been discussed.

For a more specific comparison between the microfossil assemblage suites based on diagnostic species ranges, a biostratigraphic subdivision proposed by Lange (1967) for the Devonian in the Paraná Basin, Brazil, is contrasted with the "Chitinozoa Assemblage Zones" suggested by the writer for the entire marine sediments observed from the exploratory wells on shelf and coastal region of Ghana. Lange's Biostratigraphic Subdivision of the Devonian of the Paraná Basin, Brazil, is indicated in its entirety in Table 6 for reference on the discussion below:

Interval D.1: Lower Devonian (Barren)

This interval was not observed in Ghana.

Interval D.2: Lower Devonian

Two Sub-Intervals are recognized in the Paraná Basin--D.2a: Angochitina (Ramochitina) magnifica; D.2b: Cladochitina biconstricta.

The biostratigraphic intervals of the Devonian of the Paraná Basin--with the exception of Interval D.1 which is barren--were established on the vertical range of the species described in the systematic part of this paper, as follows:

INTERVAL D.2

Sub-Int. D.2a - corresponds to the total range of Ramochitina magnifica.

Sub-Int. D.2b - total range of Cladochitina biconstricta.

INTERVAL D.3

Characterized by Cladochitina varispinosa, restricted to this interval. Lower limit based on lower range limit of the mentioned species and of Ramochitina ramosi, as well as that of the Acritarch Navifusa. --Angochitina cf. A. capillata starts in this interval. Upper limit based on the limit of overlying unit.

INTERVAL D.4

Sub-Int. D.4a - Lower limit corresponding to lower range limit of Ancyrochitina langei; upper limit based on the limit of overlying unit. Alpenachitina eisenacki and Ancyrochitina cf. A. desmea start in this unit. Associated in this unit, but not restricted to it, are Ramochitina ramosi, Angochitina cf. A. capillata, and Navifusa spp.

Sub-Int. D.4b - Lower limit established on lower range limit of Angochitina devonica and of Ancyrochitina cf. A. ancyrea. Upper limit coinciding with upper range limit of Angochitina cf. A. capillata. Associated are Ramochitina ramosi, Alpenachitina eisenacki, Ancyrochitina cf. A. desmea, Ancyrochitina langei and Navifusa.

Sub-Int. D.4c - Lower Limit based on disappearance of Alpenachitina eisenacki, Ancyrochitina cf. A. desmea, and Angochitina cf. A. capillata. Upper limit corresponding to upper range limit of Ramochitina ramosi, Ancyrochitina langei, Angochitina devonica and Ancyrochitina cf. A. ancyrea.

INTERVAL D.5

Characterized by the total range of Angochitina mourai, by the occurrence of Lagenochitina avelinoi, and by the upper range limit of Navifusa.

Table 6. Biostratigraphic Subdivision of the Paraná Basin, Brazil, South America (after Lange, 1967, p. 90).

Cladochitina biconstricta was not observed in Ghana. Only one specimen of A(R) magnifica was found in Zone B of the SE/10-1 well. Zone D of the Devonian of Ghana probably correlates with the Sub-Interval D.2b of the Paraná Basin since the Ghanaian "zone" carries Lower Devonian elements as well.

Interval D.3: Middle Devonian-Eifelian

Cladochitina varispinosa is restricted to this interval with Angochitina (Ramochitina) ramosi being long-ranging. This interval correlates closely with Zone C--Cladochitina varispinosa Assemblage Zone of Ghana. In the SE/10-1 well and UC/19-2A well, C. varispinosa is diagnostic to the zone while A(R) ramosi occurs in higher horizons in these two wells. In A-1 well, C. varispinosa and A(R) ramosi were observed in Zone B and Zone C of the well, with A(R) ramosi being the most diagnostic species of this well. Thus, the "long-ranging" of A(R) ramosi in the Devonian of Ghana corresponds to the range of this species in the Paraná Basin of Brazil. Cladochitina varispinosa, however, was observed also in the Zone A of the Devonian of Ghana which appears to correlate with Sub-Interval D.2b of the Paraná Basin, Brazil. Cladochitina varispinosa is not represented in the Sub-Interval D.2b in the Paraná Basin. Since only cutting samples were used for this project, intermixing of samples may account for the occurrence of C. varispinosa in the lower zones of the Ghana wells. It is equally probable that this species is endemic in Zone A, and both Zone A and Zone B in Ghana correlate with Interval D.3 of the Paraná Basin, Brazil.

Interval D.4: Middle Devonian-Givetian

Three Sub-Intervals, D.4a; D.4b; D.4c were proposed by

Lange for the Paraná Basin, with most of the species occurring concurrently. All the species in Interval D.4 were observed in Zone C Angochitina devonica-Angochitina (Ramochitina) ramosi Assemblage Zone and partly in lower zones in Ghana. These species are: Ancyrochitina langei, Alpenachitina eisenacki, Ancyrochitina cf. A. desmea, Ramochitina ramosi, Angochitina cf. A. capillata, Ancyrochitina cf. ancyrea, Angochitina devonica, and Navifusa spp. (acritarchs). (See Table 6 for assemblages in Sub-Intervals).

Interval D.5: Upper Devonian-Frasnian:

This Interval in the Paraná Basin is characterized by Angochitina mourai, Lagonechitina avelinoi, and the acritarch Navifusa. This Interval correlates with Zone D--Angochitina mourai Assemblage Zone in Ghana. Lagenochitina avelinoi was not observed in Ghana, but Zone D of SE/10-1 well in the west of Ghana carries several North African elements reported from the Upper Devonian of Morocco by Grignani and Mantovani (1964).

Navifusa is one of the dominant components of the acritarch assemblage in the Devonian of Ghana. The occurrence of this species from the Eifelian to Frasnian in the Paraná Basin, Brazil, appears to agree with the range of this species observed in the Devonian of Ghana.

The close similarity of micrifossil assemblage suites in Ghana, West Africa, and Brazil, South America appears to supplement the evidence of similar geologic setting of the Atlantic coasts of the two continents during the Devonian period.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

Paleozoic sediments from exploratory oil wells on the continental shelf and coastal region of Ghana, West Africa, are characterized by a rich microfossil assemblage. The distribution of the microfossils in the various wells studied indicates two major sedimentary facies, a lower marine facies of 1,010 feet thickness in the east to 1,050 feet thickness (?) in the west containing an association of abundant chitinozoans, acritarchs, spores, tasmanites, leiospheres, and scolecodonts overlain by a continental facies, of about 750 feet thickness in the east to 1,990 feet thickness in the west, carrying almost exclusively spores. The upper 1,590 feet thickness of the continental section in the west is barren of microfossils. A distinct acritarch assemblage occurs terminally of the continental facies which is 150 feet thick in the east to less than 50 feet thick in the west.

A detailed study of the chitinozoans and the acritarchs from the sediments indicates several elements in the Ghanaian assemblage common to Lower to Upper Devonian chitinozoan and acritarch species reported from Europe, North Africa, North America and especially, an upper Lower Devonian (Emsian) to lower Upper Devonian (Frasnian) chitinozoan and acritarch assemblage of Brazil, South America. Thus, it appears that the Ghanaian chitinozoan and acritarch assemblage represents an upper

Lower Devonian (Emsian) to an early Upper Devonian (Frasnian) age.

Four tentative Chitinozoa Assemblage Zones have been proposed for the the marine Devonian sediments from the wells as follows, in descending order:

Zone D: Angochitina mourai Assemblage Zone

Zone C: Angochitina devonica-Angochitina (Ramochitina) ramosi Assemblage Zone

Zone B: Cladochitina varispinosa Assemblage Zone

Zone A: Ancyrochitina sp. 6 Assemblage Zone

Overlaps, as well as local variations of the microfossil content of the various zones occur in the wells studied. As such, the zones in the west are described as "Western Chitinozoa Assemblage Zones" defined by the chitinozoan assemblage in the SE/10-1 well, and the zones in the east are described as "Eastern Chitinozoa Assemblage Zones" defined by the chitinozoan assemblage in the A-1 well. The objective of this distinction is to emphasize local variations in the microfossil assemblage in the west and east coast of Ghana and to establish a biostratigraphic framework which can be readily applied for correlation of wells on the entire shelf and coastal region of Ghana.

Relationships between the chitinozoan diversity and acritarch diversity as well as general spore distribution at various stratigraphic sections of the wells studied suggest that the Devonian Sea in Ghana advanced from the west in relation to the present magnetic pole position. The Sea was very shallow of an epicontinental platform type and for a very long period of time periodic fluctuations in water level accompanied by coarse clastic discharges occurred. Regression of the Sea was very

slow, and in the west deltaic conditions probably followed the marine invasion. Following the complete withdrawal of the Sea, probably in the early Upper Devonian (Frasnian), continental clastic materials were deposited. This was followed by brackish water conditions in which some acritarchs flourished, particularly in the east.

This evidence of a single and probably a continuous sedimentation cycle for sediments of Devonian age observed from the exploratory oil wells on the shelf and coastal region of Ghana appears to conflict with previous geologic data for Devonian sediments outcropping along the coast.

The Accraian Series and the Sekondi Series are considered to belong to separate sedimentation cycles, with the Accraian Series representing Lower or Middle Devonian age and the Sekondi Series corresponding to Upper Devonian or Lower Carboniferous position, and according to Crow (1952) the lower Sekondi Series (Ajua Shales) were deposited from glacial melt water.

The lithology of the various wells studied is closely similar to either the Accraian Series or the Sekondi Series, and more especially, the upper sections of the SE/10-1 well located close to the outcrop of the Sekondi Series at the coast (Fig. 5) with barren coarse clastics and occasional chert bands are similar to the lithologies of the upper units of the Sekondi Series (Table 1).

Comparison of thicknesses for the Sekondi Series and the Accraian Series suggested by Crow (1952) and Saul (*in* Saul *et al.*, 1963), respectively, with thicknesses of sediments of Devonian age observed from wells on the shelf and close to the outcrops of the Sekondi

Series and Accraian Series indicates some interesting relationships.

Crow (op. cit.) estimated the thickness of the Sekondi Series to be 3,740-4,000 feet. The thickness of the Devonian sediments from the SE/10-1 well located close to the outcrop of the Sekondi Series is 3,725 feet with the lower 675 feet thickness of the sediments missing, according to the Ghana Geological Survey (personal communication). The thickness of the Accraian Series as estimated by Saul (op. cit.) is 2,865 feet compared with 2,370 feet thickness for the Devonian sediments observed from the UC/19-2A well located on the shelf and close to the outcrop of the Accraian Series. If the sediments from the SE/10-1 well and the UC/19-2A are synchronous (Fig. 12), it follows that their equivalents outcropping at the coast, i.e., the Sekondi Series and the Accraian Series, respectively, are synchronous.

The writer believes that the different ages proposed by various workers for the Accraian Series (Lower or Middle Devonian) and the Sekondi Series (Devonian or Lower Carboniferous) which are essentially based on usually poorly preserved fossils collected from single and restricted, narrow sections within each series may correspond to the basal stratigraphic section of the marine sediments observed from the wells for the Accraian Series and the upper section of the marine sediments for the Sekondi Series. It is significant to note that both in the SE/10-1 well and UC/19-2A well distinct carbonaceous shales occur above the marine sediments. These carbonaceous shales probably correspond to the stratigraphic interval of the Sekondi Series from which Mensah and Chaloner (1971) dated the Sekondi Series on floral content to be Lower Carboniferous age.

Sediments of Devonian age occur widespread in several localities in West Africa. According to Legault (oral communication) sediments of Middle Devonian age have been observed from an offshore well in the Republic of Togo, Ghana's neighbour to the east. No carboniferous sediments have been reported from any locality in West Africa, apart from the Early Carboniferous age suggested by some workers for the Sekondi Series in Ghana. However, the next phase of this project, which deals exclusively with the spore assemblage, will throw more light on the exact age of the continental sediments overlying the marine sediments.

Even though the lower sediments from the SE/10-1 well in the west were not observed, the basal sediments from the adjacent wells SE/13-1 and SE/13-2 processed proved to be distinctly marine. Thus, Crow's supposition that the lower Sekondi Series (Ajua Shales) were deposited from glacial melt water appears to be unsubstantiated if the Sekondi Series is synchronous with the Devonian sediments observed from the exploratory oil wells on the shelf and coastal region of Ghana.

The four tentative Chitinozoa Assemblage Zones proposed by the writer for the Devonian sediments in Ghana closely correlate with similar zones proposed by Lange (1967) for Devonian sediments in the Paraná Basin, Brazil, both in microfossil content and species ranges. This observation reinforces evidence of similar geologic setting on both sides of the Atlantic coasts of West Africa and South America.

CHAPTER IX

SYSTEMATIC DESCRIPTIONS

Introduction

Classification of the Chitinozoa

Classification of any extinct group of organisms whose relationships with each other or with living organisms are unknown or uncertain is usually very difficult. The classification of the Chitinozoa is not an exception to this fact.

Eisenack, in his several years of experience with the Chitinozoa, dating from the early 1930's proposed a system of classification for this group of microfossils which is largely empirical, but which is still widely used by many workers. Recently, however, four different schemes of classification of chitinozoans have been proposed by some authors: van Oyen and Calandra (1963), Jansonius (1964, 1967, 1970), Tappan (1966), and Taugourdeau (1966).

Perhaps, of special significance to the writer in this work is the classification proposed by Jansonius, which is based on the character of the operculum and its "complex form" the prosome.

Jansonius divided the Chitinozoa into two supra-generic groups: "Simpleoperculati" and "Complexoperculati". The "Simpleoperculati" have simple operculum and consist of two families: Desmochitinidae - those with "external operculum" and Conochitinidae - those

with "recessive operculum". The "Complexoperculati" have more developed "recessive operculum" (prosome) and consist of two families: Sphaerochitinidae - those with simple prosome and usually lacking differentiation of the aboral pole, and Tanuchitinidae - those with highly developed prosome complex and more or less elaborate differentiation of the aboral pole.

In my restricted experience with the Chitinozoa from the Devonian of Ghana, "various phases" of the prosome have been observed under the transmitted light microscope, even within a single species of Chitinozoa. The prosome of some specimens of a species may be solid and plug-like within the neck of the organism, annulated or consisting of a series of circular discs within the neck, being ejected from the neck, sunk into the body chamber, or entirely absent from the organism (e.g.: Pl. III, figs. 1 - 6; Pl. IV, figs. 1 - 5, 7 - 8). The significance of this phenomenon observed for the prosome of specimens usually belonging to the same species is not known to the writer.

Urban (1972, p. 10) however, by studying the prosome with the S.E.M. (scanning electron microscope) has indicated that the morphology of the prosome is more elaborate and complex than previously indicated by some authors. Urban has shown that two variations of the prosome commonly occur in Angochitina devonica as well as many other species. One appears as a solid plug while the other is an annulated tube. The annulated type consists of several circular discs which are unornamented on the oral surface but have fine spines on the aboral surface. According to Urban, these two types of prosome in individuals that are otherwise virtually identical may be related to the "reproductive process" of the organism.

It appears that more detailed study of the prosome is still necessary and its "various phases" in a species must be critically appraised before it can be used as a basis for the classification of the Chitinozoa.

The classification of the Chitinozoa adopted in this work is the empirical classification scheme proposed by Eisenack.

Difficulties in the Empirical Classification Scheme used in this Work

In applying the empirical classification scheme for chitinozoans several difficulties were encountered by the writer, among which are the following: errors in measurements due to preservation effects; errors in measurements due to disorientation of specimens on slide; and degradation effects on ornamentation.

Errors in Measurements due to Preservation Effects

The character and shape of any fossil is related to the degree of preservation during burial. Various deformation patterns due to preservation were observed in the Chitinozoa recovered from the Devonian sediments in Ghana. Among these deformations are: folding of the tests, particularly at the base (Pl. XI, fig. 9 contrast fig. 8; Pl. XIV, figs. 1, 2 contrast figs. 3, 4), and general contraction of the test (Pl. XI, fig. 6 contrast fig. 5). In well preserved and transparent materials it is easy to spot these deformations in the specimens, but when the materials are opaque, as most chitinozoans recovered from various sediments usually are, it is often difficult to spot these deformations, thus measurements recorded for specimens

become very subjective and unreliable.

Errors in Measurements due to Disorientation of Specimens on Slide

This is another source of subjective and unreliable measurements, particularly in opaque specimens of chinozoans. Since there is no control in the orientation of microscopic specimens, such as chitozoans on a slide during preparation, significant number of the specimens become disoriented (Pl. XI, fig. 15 contrast figs. 11, 12). These disoriented specimens may not be evident when the materials are opaque.

Tables 8 and 9 are summaries of measurements made on *Ancyrochitina* spp. and *Angochitina* spp., respectively, from the Devonian sediments in Ghana. Although apparently better preserved and well oriented specimens were measured, significant variations occur in the various parameters used in the measurements. Some of these variations are due to natural variations in the various species but others might be due to preservational effects and disorientation of the specimens on the slide which were not obvious.

Degradation Effects on Ornamentation

Erosion of ornamentation is a very common feature in chitinozoans. At times impressions such as spine bases are quite evident on the test of the chitinozoan even when the spines are eroded, but in some cases the degradation of the ornamentation on the Chitinozoa are so very complete that there is no impression or trace of it on the test of the organism (Pl. IX, figs. 1-7 contrast figs. 8,9).

As an attempt to illustrate ornamentation patterns in Chi-

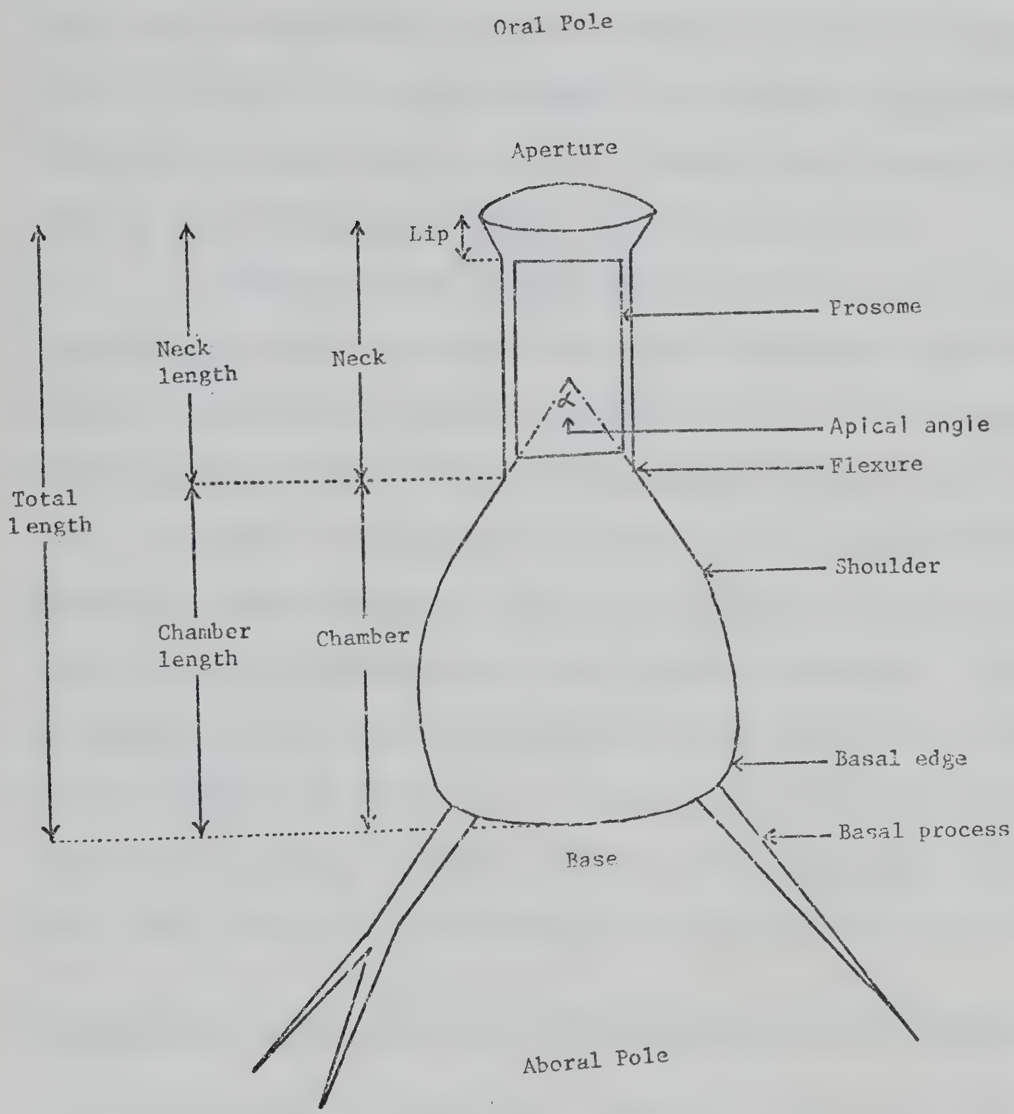

Figure 14. Diagrammatic Lateral View of a Generalized Chitinozoan Test with Terminology of the Major Features.

tinozoa type E which shows enormous variation in the length of the neck (Pl. XV, figs. 2, 3, 4) the S.E.M. (scanning electron microscope) was used in photographing one specimen (Pl. II, figs. 3, 4). Although part of the ornamentation is clearly shown on the specimen photographed with the S.E.M. it is evident however, that complete degradation of the ornamentation would result in the wall becoming very smooth without any trace of the ornamentation pattern (cf. Pl. XV, fig. 2).

All the various factors in preservation of chitinozoans discussed above introduce enormous problems in Chitinozoa classification based on the empirical scheme. The use of the S.E.M. in studying the Chitinozoa would greatly help in bringing out details in wall microstructure, variations in ornamentation patterns due to preservation effects and various other parameters which are important in understanding and classifying the Chitinozoa with some degree of confidence. There is an attempt in this direction (Urban and Kline, 1970; Urban, 1972). However, the use of the S.E.M. in studying the Chitinozoa is not only expensive but appears impractical when a large population of specimens, which the stratigraphic paleontologist has to cope with, are studied.

Morphological Terms Used in the Classification of the Chitinozoa

The morphological terms which have been used in the empirical classification scheme adopted in this work are indicated in Figure 14.

Classification of the Acritarcha

The classification scheme of the Acritarcha adopted in this

work is that proposed by Downie, Evitt and Sargeant (1963). In this classification, the Group Acritarcha is divided into less rigid, flexible supra-generic groups not based on type genera. The name of each supra-generic group being based on characteristic morphological features, combined with the ending "morphitae". This appears to be the most practical way of subdividing such a diverse group as the acritarchs.

Recently, however, the scanning electron microscope has been used to study the wall micro-structure and ornamentations as bases for classifying the acritarchs (Loeblich, 1970; Tappan and Loeblich, 1971). Downie (1973) has proposed a number of related groups of the acritarchs and has suggested evolutionary trends for them.

The identification of the various acritarch genera and species has been based on readily available literature on the group and may lack refinement. The objective here is to establish a qualitative relationship of association between the number of Chitinozoa species observed and the number of Acritarcha species observed in a sample from a specific interval. Thus, a few acritarch forms have been figured and described or remarked but because they occur very rarely and because designating them to a separate species is highly subjective they have not been statistically used in the relationship nor indicated on the range charts.

Tasmanites and Leiospheres, although occurring very commonly in the assemblage have also been omitted because of their apparent limited use in biostratigraphy.

Order CHITINOZOA Eisenack, 1931

Genus ALPENACHITINA Dunn and Miller, 1964

Type species: Alpenachitina eisenacki Dunn and Miller, 1964

DIAGNOSIS: Test flask shaped with conical body chamber and a cylindrical neck characterized by two or more separate and distinct horizontal rows of stout spines which may be unbranched, bifurcated, or multibranched.

ALPENACHITINA EISENACKI Dunn and Miller, 1964

Plate V, Figures 12-14

1964: Alpenachitina eisenacki Dunn and Miller, Jour. Paleont. 38(4), p. 725-728, Pl. 119, figs. 1-12.

1967: Alpenachitina eisenacki Dunn and Miller, Lange, Bol. Paranaense Geociênc. 21/22, p. 65, Pl. 1, figs. 1-3.

1971: Alpenachitina eisenacki Dunn and Miller, Costa, An. Acad. Brasil. Ciênc., 43, p. 215 (Fig. 1).

1972: Alpenachitina eisenacki Dunn and Miller, Urban, Bull. Amer. Paleont. 63 (275), P. 11, Pl. 1, fig. 1.

DESCRIPTION: Test medium size with sub-cylindrical body chamber expanded at the base and slightly tapered orally; neck cylindrical, about 2/5 the total length of the test; flexure broad, distinct; shoulder distinct; wall ornamented with a row of simple, long spines at about the middle of the cylindrical neck and other rows of multibranched

spines at about the base of the shoulder, and at the basal edge; in some specimens simple spines may occur at the base of the neck, and long, multifurcate spines may occur at the lip; prosome plug-like within the neck but are usually lost in many specimens observed.

DIMENSIONS (in microns): 5 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	146-174	56-71	73-93	40-46	40-46
Mean:	162	63	84	43	43

ILLUSTRATED SPECIMENS:

Pl. V, fig. 12, Sample UC/19-2A/8550/2, Co-ordinate 117.0/34.9

Pl. V, fig. 13, Sample UC/19-2A/8480/2, Co-ordinate 122.5/48.5

Pl. V, fig. 14, Sample UC/19-2A/8500/6, Co-ordinate 124.5/48.5

LOCALITY: This species occurs in all the three wells studied but are rare.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first described from the Middle Devonian Alpena Limestone, Michigan, U.S.A. by Dunn and Miller (1964). Lange (1967) and Costa (1971) have reported it from Middle Devonian sediments in Brazil, South America, and Urban (1972) has recorded it from the Middle Devonian Cedar Valley Formation of Iowa, U.S.A. The species has also been reported from the Middle Devonian (Givetian) Hamilton Group in southern Ontario, Canada (Legault, 1971, Unpubl. Ph. D. Thesis). This species appears restricted to the Middle Devonian.

REMARKS: The specimens of this species recovered from the Ghanaian sediments are generally poorly preserved. However, the rows of spines on the tests were quite characteristic. The Ghanaian specimens are generally similar to other specimens recorded elsewhere.

ALPENACHITINA sp. 1

Plate V, Figures 15, 16

Text--figure 19a

DESCRIPTION: Test medium size with sub-cylindrical body chamber expanded at the base and slightly tapering orally; neck cylindrical, about 1/3 to 2/5 total length of the test; flexure distinct; shoulder distinct; basal edge sharp; base convex; wall ornamented with simple and bifurcate spines 20-31 microns long and 4.2-5.4 microns maximum diameter, these spines occur on the lip, lower part of the neck to upper part of the body chamber; similar spines may occur at the basal edge, but rare; prosome plug-like within the neck or absent.

DIMENSIONS (in microns): 5 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
	171	53	84	40	40
Range:	155-171	47-53	85-87	31-40	37-40
Mean:	165	50	86	35	37

ILLUSTRATED SPECIMENS:

Pl. V, fig. 16, Sample UC/19-2A, Co-ordinate 119.1/35.5

Pl. V, fig. 15, Sample A-1/1266-1268/2, Co-ordinate 111.7/30.7

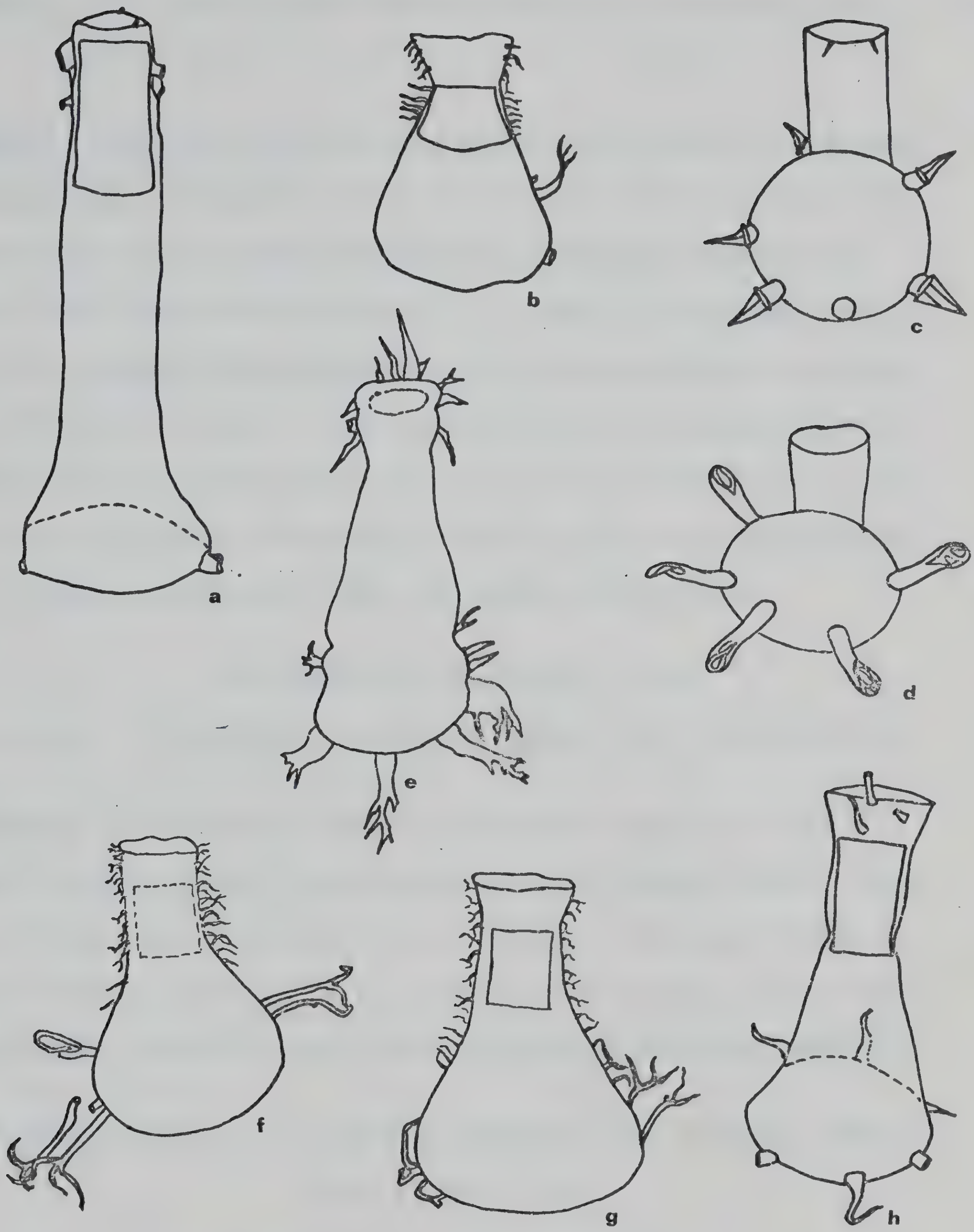

Figure 15. Morphological Variability of some *Ancyrochitina* spp. from the Devonian of Ghana (Semi-diagrammatic. Magnification of all illustrated specimens X300). 15a, *Ancyrochitina* sp. cf. *A. gumersinda* Cramer; 15b, *Ancyrochitina* sp. cf. *A.* sp. Jansonius; 15c-d, *Ancyrochitina* sp. 2; 15e, *?Ancyrochitina* sp. 4; 15f-g, *Ancyrochitina* sp. 7; 15h, *Ancyrochitina* sp. 6.

LOCALITY: This species was observed from all the three wells but is rare.

REMARKS: These specimens have been tentatively assigned to the genus Alpenachitina Dunn and Miller on the basis of the similarity in the shape of the test to some specimens of A. eisenacki which were observed from the Ghanaian samples (Pl. V, figs. 13, 14 contrast figs. 15, 16). Alpenachitina eisenacki however, has the spinose ornamentation distinctly in rows at the neck, shoulder and at the basal edge. Cladochitina varispinosa Lange which also occurs commonly in the samples, has the spinose ornamentation covering the entire body chamber and the neck, besides, the spines are usually multibranched.

Genus ANCYROCHITINA Eisenack, 1955

Type Species: Ancyrochitina ancyrea (Eisenack, 1931) Eisenack, 1955

DIAGNOSIS: Chitinozoa with nearly cylindrical neck, 1/2 to 2/3 of overall length of test, conical or more rarely rounded chamber. Base more or less even, slightly concave or convex. Peripheral margin with relatively few (about 4-10, generally 5-8) strong, more or less long, simple, furcate or also rather irregularly branched appendages.

ANCYROCHITINA sp. cf. A. ANCYREA (Eisenack, 1931) Eisenack, 1955

Plate I, Figures 1-2

Plate III, Figures 1-8, 12, 13

1931: Conochitina ancyrea Eisenack, Paläeont. Z. 13 (1/2), p. 88, text-fig. 2, Pl. 2, figs. 8, 11, Pl. 4, fig. 4.

1955: Ancyrochitina ancyrea (Eisenack) Eisenack, Senck. Leth. 36 (1/2), Pl. 2, figs. 8, 11, Pl. 4, fig. 4.

1960: Ancyrochitina ancyrea Eisenack Taugourdeau and Jakhowsky, Rev. Inst. Fr. Pétrole, XV(9), p. 1218, Pl. I, figs. 2-8.

1962: Ancyrochitina ancyrea Eisenack, Beju and Danet, Petrol şi Gaze, 13 (12), p. 529, Pl. 1, figs. 1-9.

1964: Ancyrochitina ancyrea Eisenack, N. Jb. Geol. Paläeont. Abh. 120. p. 324, Pl. 27, figs. 7, 15; Pl. 28, figs. 6, 7.

1964: Ancyrochitina ancyrea Eisenack, Sommer and van Boekel, An. Acad. Bras. Ci., 36(4), p. 427, text-fig. 5, Pl. 1, fig. 2, Pl. 2, figs. 1, 2.

1967: Ancyrochitina cf. A. ancyrea (Eisenack.), Lange, Bol. Paranaense Geociências 21/22, p. 68, Pl. 1, fig. 7.

1968: Ancyrochitina ancyrea Eisenack, Jardine and Yapaudjian, Rev. Inst. Fr. Pétrole, XXIII (4), Pl. 5, fig. 6.

1971: Ancyrochitina ancyrea Eisenack, Costa Dept. Nacional Produc. Min. Div. Geol. Min. 255, p. 55, Pl. X, figs. 2-4.

1971: Ancyrochitina ancyrea Eisenack, Costa, An. Acad. Brasil, Ciênc., 43, p. 217, (Fig. 2).

DESCRIPTION: Test medium size, cylindro-conical; length of neck about 1/2 total length of test; flexure broad, distinct; shoulder absent or weakly developed; basal edge rounded with four to about ten simple, bifurcate or multifurcate basal processes, or occasionally with club-like spongy textured basal processes; basal processes of many specimens broken off, but their grapnel shaped endings are usually evident; base slightly convex; wall smooth; simple, bifurcate, or multi-branched spines occur at the lip; occasionally, club-like spongy-textured ap-

pendages may occur at the lip of some specimens which have similar appendages at the basal edge; prosome, short, plug-like or annulated with circular discs within the neck; some specimens are devoid of the prosome.

DIMENSIONS (in microns): 20 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	124-180	34-93	84-112	25-50	25-50
Mean:	140	65	87	37	37

ILLUSTRATED SPECIMENS:

Pl. I, figs. 1,2, Sample UC/19-2A/8520

Pl. III, fig. 1, Sample UC/19-2A/9010/1, Co-ordinate 114.8/46.1

Pl. III, fig. 2, Sample A-1/1336-1338/1, Co-ordinate 114.2/35.3

Pl. III, fig. 3, Sample SE/10-1/8250/1, Co-ordinate 123.6/28.0

Pl. III, fig. 4, Sample UC/19-2A/8700/2, Co-ordinate 116.5/46.4

Pl. III, fig. 5, Sample UC/19-2A/8500/1, Co-ordinate 116.5/33.0

Pl. III, fig. 6, Sample A-1/1266-1268/3, Co-ordinate 119.0/34.8

Pl. III, fig. 7, Sample UC/19-2A/8260/4, Co-ordinate 121.3/32.7

Pl. III, fig. 8, Sample UC/19-2A/8260/3, Co-ordinate 112.8/29.1

Pl. III, fig. 12, Sample UC/19-2A8350/2, Co-ordinate 122.9/63.5

Pl. III, fig. 13, Sample UC/19-2A/9010/1, Co-ordinate 127.4/36.8

LOCALITY: This species forms one of the dominant components of the chitinozoan assemblage in all the three wells studied.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first described from the Silurian of the Baltic Region by Eisenack. The species has

also been observed from various Silurian sediments in Europe (Beju and Danet, 1962; Jardine and Yapaudjian, 1968). It has also been reported from Silurian and Devonian sediments in the Sahara (Taugourdeau and Jekhowsky, 1960), Silurian and Middle Devonian in Brazil (Sommer and van Boekel, 1964; Lange, 1967; Costa, 1971). The stratigraphic range of the species is Lower Silurian to Lower Upper Devonian (Frasnian), according to Taugourdeau (1966).

REMARKS: The diagnostic features of this species as described by Eisenack are "... peripheral margin occupied by 4 to 10 (generally 6 to 8) more or less elongate, distally diminishing appendages which terminate in anchor-like furcations, but which can also be antler-like or irregularly branched ..."

Some specimens of *Ancyrochitina* from the Devonian of Ghana compared with *A. ancyrea* have similar basal processes as described by Eisenack, others have simple, club-like, spongy-textured basal processes, and a large number of them have the basal processes broken off, but the general shape of their tests are comparable to *A. ancyrea*. Some specimens of this species observed from Ghana also have somewhat ramified appendages similar to those of *A. desmea* Eisenack. These ramified appendages are located at the lip and not half-way between the neck as is the case of *A. desmea*.

ANCYROCHITINA STRIATA Taugourdeau, 1963

Plate IV, Figures 1-5, 7, 8

Plate XVII, Figures 11, 12

1963: *Ancyrochitina striata* Taugourdeau, Rev. Micropaléo. 6(3), p. 131,

Pl. 1, figs, 7-16, Pl. 2, fig. 17.

1966: Ancyrochitina striata Taugourdeau, Mem. Soc. Geol. France, 104, Pl. II, fig. 52, Pl. IV, figs, 87, 94.

1968: Ancyrochitina striata Taugourdeau, van Boekel, Dept. Nacional Prod. Min. Div. Geol. Min. 146, p. 9, Pl. III, figs. 2, 3.

1971: Ancyrochitina striata Taugourdeau, Costa, An. Acad. Brasil. Ciênc., 43, p. 221, (Fig. 12).

DESCRIPTION: Test medium size, flask-shaped; body chamber high conical; neck short, 1/4 to 1/3 total length of the test; flexure broad, distinct; shoulder absent or weakly developed; basal edge sharp with a few, simple, elongate, tapering basal processes which are usually broken off in most of the specimens examined; base flat to convex; wall folded along the vertical axis of the text, occasionally folding is criss-crossed; a few thin spines may occur at the lip; prosome, short, plug-like or long and annulated within the neck, some specimens are devoid of the prosome.

DIMENSIONS (in microns): 20 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	130-180	37-46	70-96	28-56	26-44
Mean:	146	40	87	37	34

ILLUSTRATED SPECIMENS:

Pl. IV, fig. 1, Sample SE/10-1/8400/1, Co-ordinate 125.0/35.6

Pl. IV, fig. 2, Sample A-1/1318-1320/1, Co-ordinate 118.6/46.3

Pl. IV, fig. 3 Sample A-1/1318-1320/2, Co-ordinate 115.2/39.8

Pl. IV, fig. 4, Sample A-1/1318-1320/4, Co-ordinate 117.6/28.5

Pl. IV, fig. 5, Sample A-1/1266-1268/1, Co-ordinate 119.2/32.4

Pl. IV, fig. 7, Sample UC/19-2A/8260/2, Co-ordinate 117.8/31.2

Pl. IV, fig. 8, Sample UC/19-2A/8290/3, Co-ordinate 112.0/34.1

Pl. XVII, fig. 11, Sample SE/10-1/8850/2, Co-ordinate 118.5/60.3

Pl. XVII, fig. 12, Sample SE/10-1/8800/3, Co-ordinate 124.5/35.9

LOCALITY: This species occurs commonly in all the three wells. In the UC/19-2A well, the species occurs commonly within the interval 8,260-8,450 feet depth. In the SE/10-1 well it occurs between 8,240-8,650 feet and in the A-1 well it was observed between 4,178-4,184 feet.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first described from the Famennian of the Sahara, North Africa, (Taugourdeau, 1963). It has been reported from the Middle Devonian in Brazil, South America (Boekel, 1968; Costa, 1971). The species appears restricted to the Middle and Upper Devonian.

REMARKS: The characteristic features of this species are its high conical body chamber, short neck, and the distinctive folding of the wall along the vertical axis of the test. The Ghanaian specimens of this species are closely similar to the Saharan and Brazilian specimens.

ANCYROCHITINA sp. cf. A. CORNIGERA Collinson and Scott, 1958

Plate IV, Figures 9-12

1958: Ancyrochitina cornigera Collinson and Scott, Illinois State

Geol. Surv. Circ. 247, p. 19, Pl. 2, figs. 4, 5, 15-19, text-fig. 8.

1959: Ancyrochitina cornigera Collinson and Scott, Dunn, Jour. Paleont. 33(6), p. 1013, Pl. 126, figs. 17-21.

1971: Ancyrochitina cf. A. cornigera Collinson and Scott, Legault, Unpubl. Ph.D. Thesis, Univ. Oklahoma, p. 89, Pl. I, figs. 3-9, Pl. II, figs. 1-3.

1971: Ancyrochitina cornigera Collinson and Scott, Costa, An. Acad. Brasil Ciênc., 43, p. 218, (Fig. 4).

1972: Ancyrochitina cornigera Collinson and Scott, Urban, Bull. Amer. Paleont. 63 (275), p. 12, Pl. 1, figs. 7-12.

DESCRIPTION: Test medium size with high conical body chamber and a short cylindrical to sub-cylindrical neck, 1/4 to 1/3 of the total length of the test; neck usually flaring orally; basal edge sharp, with a few (commonly less than six) short, simple spine-like basal processes of about 37 microns long and 12 microns maximum diameter; these basal processes taper rapidly and may be straight or curved inwards towards the base of the body chamber; base flat to convex; wall smooth, lip thin, transparent and may bear long thin spines; prosome short, plug-like at the base of the neck.

DIMENSIONS (in microns): 10 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	124-205	31-50	78-90	31-43	35-47
Mean:	155	46	84	37	40

ILLUSTRATED SPECIMENS:

Pl. IV, fig. 9, Sample UC/19-2A/8350/4, Co-ordinate 114.3/28.8

Pl. IV, fig. 10, Sample UC/19-2A/9010/2, Co-ordinate 115.7/56.7

Pl. IV, fig. 11; Sample UC/19-2A/8350/1, Co-ordinate 123.2/34.2

Pl. IV, fig. 12, Sample UC/19-2A/9010/4, Co-ordinate 115.7/68.0

LOCALITY: This species occurs in all the three wells studied.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first described from the Middle Devonian Cedar Valley Formation of Illinois (Collinson and Scott, 1958). It has been reported from the same formation in Iowa (Dunn, 1959; Urban, 1972), and Middle Devonian Hamilton Group of southern Ontario (Legault, 1971, Unpubl. Ph.D. Thesis). The species has also been recorded from the Middle Devonian in Brazil (Costa, 1971). The species appears restricted to the Middle Devonian.

REMARKS: The Ghanaian specimens of this species have much shorter and flaring necks. They have general resemblence in the shape of the test and the nature of the basal processes, particularly to the Cedar Valley Formation specimens.

ANCYROCHITINA LANGEI Sommer and van Boekel, 1964

Plate V, Figures 1-4

1964: Ancyrochitina langei Sommer and van Boekel, An. Acad. Bras. Ci. 36(4), p. 427, Pl. 1, fig. 1, Pl. 2, figs. 5, 6, text-fig. 4.

1967: Ancyrochitina langei Sommer and van Boekel, Lange, Bol. Paranaense Geociências 21/22, p. 70, Pl. 1, figs. 8, 9.

1968: Ancyrochitina langei Sommer and van Boekel, Dept. Nacional Prod.

Min. Div. Geol. Min. 146, p. 10, Pl. III, fig. 6.

1971: Ancyrochitina langei Sommer and van Boekel, Costa, An. Acad. Brasil, Ciênc. 43, p. 219, fig. 7.

1971: Ancyrochitina cf. A. langei Sommer and van Boekel, Legault, Unpubl. Ph.D. Thesis, Univ. Oklahoma, p. 95, Pl. II, figs. 11, 12, Pl. III, figs. 1-9.

DESCRIPTION: Test cylindro-conical; length of neck about 2/5 the overall length of the test; lip occasionally slightly flared; flexure broad; shoulder absent; basal edge sharp but rounded with a few (six or less) simple, stout or occasionally bifurcate spine-like basal processes 31-40 microns long and 6.2-9.3 microns maximum diameter; base flat to convex; lip ornamented with variable spines which are usually short and stout or occasionally thin and long; wall smooth; prosome short to elongate, plug-like, within the neck.

DIMENSIONS (in microns): 20 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	155-217	62-112	78-109	37-47	37-47
Mean:	201	84	84	43	44

ILLUSTRATED SPECIMENS:

Pl. V, fig. 1, Sample UC/19-2A/8550/1, Co-ordinate 122.0/61.0

Pl. V, fig. 2, Sample UC/19-2A/9010/3, Co-ordinate 119.0/28.4

Pl. V, fig. 3, Sample UC/19-2A/8500/5, Co-ordinate 115.0/22.5

Pl. V, fig. 4, Sample UC/19-2A/8880/1, Co-ordinate 121.6/63.3

LOCALITY: This species occurs commonly in all the three wells studied.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species occurs commonly in Middle Devonian sediments in Brazil from which it was first described (Sommer and van Boekel, 1964; Lange, 1967, Boekel, 1968; Costa, 1971). The species has also been recorded from the Middle Devonian Hamilton Group in southern Ontario (Legault, 1971, Unpubl. Ph.D. Thesis). The species appears restricted to the Middle Devonian.

REMARKS: Sommer and van Boekel (1964 *in* Lange, 1967, p. 70) in their description of this species indicated that "the principal character of this species is the presence of regularly developed spines in variable number, around the oral tube. These spines seem to be of a different nature as the basal appendices: they are shorter and thinner". Two to six "basal appendices" were recorded for the Brazilian specimens and were described as "simple developed, stouter at the base, tapering to extremity, slightly curved". All the features described for the Brazilian specimens of this species were observed from the Ghanaian specimens but in addition to these, some specimens have bifurcate basal processes (e.g.: Pl. V, fig. 2). This variety of *A. langei* differs distinctly from *A.* sp. cf. *A. ancyrea* found from the Ghanian Devonian sediments by their higher conical body chambers.

The overall length of the Ghanaian specimens ranges between 187-217 microns as compared with 140-228 microns recorded by Lange (op. cit.) for the Brazilian specimens.

ANCYROCHITINA sp. cf. A. GUMERSINDA Cramer, 1964

Plate V, Figures 5, 6(?), 7(?)

Text-figure 15a

1964: *Ancyrochitina gumersinda* Cramer, Leidse Geol. Med. 30, p. 339,

Pl. XXII, fig. 16, text-fig. 41.

DESCRIPTION: Test funnel-shaped with short conical body chamber and a long cylindrical neck; basal edge rounded with a few (two or more) simple basal processes which are usually broken off; base convex; wall smooth; prosome short, elongate, plug-like within the upper portion of the neck.

DIMENSIONS (in microns): 6 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	220-290	114-220	80-103	48-52	50-51
Mean:	244	159	93	50	50

ILLUSTRATED SPECIMENS:

Pl. V, fig. 5, Sample UC/19-2A/8880/4, Co-ordinate 125.0/55.8

Pl. V, fig. 6, Sample UC/19-2A/9010/1, Co-ordinate 115.0/49.7

Pl. V, fig. 7, Sample UC/19-2A/8880/1, Co-ordinate 121.6/48.0

LOCALITY: This species is rare. A few specimens were found in the UC/19-2A well within 8880-9010 ft. depth, and one specimen (not indicated on range chart) from A-1 well at about 4,798-4,805 ft. depth in the well.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first described from the Lower Devonian in NW Spain (Cramer, 1964).

REMARKS: The disporportionately long, cylindrical necks observed for the Ghanaian specimens are closely similar to those of the Spanish

specimens. However, some specimens observed have relatively higher conical body chambers and appear to be highly variant forms of A. langei (Pl. V, figs. 6, 7).

The size range of the Ghanaian specimens of A. gumersinda is 220-290 microns as compared with 225-250 microns recorded by Cramer for the Spanish specimens.

ANCYROCHITINA TOMENTOSA Taugourdeau and Jekhowsky, 1960

Plate VI, Figures 9-11

1960: Ancyrochitina tomentosa Taugourdeau and Jekhowsky, Rev. Inst. Fr. Pétrole XV(9), p. 1220, Pl. II, figs. 27, 28.

1962: Ancyrochitina tomentosa Taugourdeau and Jekhowsky, Taugourdeau, Rev. Micropaléo., 4(4), p.231, Pl. I, figs. 8-11.

1965: Ancyrochitina tomentosa Taugourdeau and Jekhowsky, Taugourdeau, Rev. Micropaléo., 8(2), p. 65, Pl. 1, figs. 4-11.

1966: Ancyrochitina tomentosa Taugourdeau and Jekhowsky, Taugourdeau, Mem. Soc. Geol. France, 104, Pl. II, figs. 30-31.

1967: Ancyrochitina tomentosa Taugourdeau and Jekhowsky, Beju, Rev. Paleobot. and Palynol., 5(1-4), Pl. II, figs. 11, 12.

1971: Ancyrochitina tomentosa Taugourdeau and Jekhowsky, Legault, Unpubl. Ph. D. Thesis, Univ. Oklahoma, p. 102, Pl. IV, fig. 2.

DESCRIPTION: Test medium size, cylindro-conical; length of neck about 2/5 the total length of the test; flexure distinct, broad; shoulder weakly developed to absent; basal edge broadly rounded with thick, elongate, often bifurcate spine-like processes; base convex; wall ornamented with randomly distributed simple and bifurcate spines; prosome

dark, short, plug-like within the neck.

DIMENSIONS (in microns): 20 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	135-189	43-83	73-97	37-45	43-47
Mean:	148	65	85	40	46

ILLUSTRATED SPECIMENS:

Pl. VI, fig. 9, Sample SE/10-1/8300/1, Co-ordinate 122.6/38.5

Pl. VI, fig. 10, Sample SE/10-1/8300/1, Co-ordinate 120.8/35.6

Pl. VI, fig. 11, Sample SE/10-1/8300/2, Co-ordinate 115.0/30.8

LOCALITY: This species occurs commonly in all the three wells studied. In the SE/10-1 well, the species was found between 8,240-9,050 ft. depth. In the UC/19-2A well, the species occurs between 8,480-9,010 feet, and in the A-1 well, it was observed between 4,160-4,750 feet.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species has been recorded from the Silurian-Middle Devonian in the Sahara (Taugourdeau and Jekhowsky, 1960), Middle Devonian (Eifelian-Givetian) in Edjele, Sahara (Taugourdeau, 1962); Upper Devonian (Middle Frasnian), Boulonnais (Taugourdeau, 1965); Middle Devonian, Morocco (Grignani and Mantovani, 1964). The species has also been reported from the Lower Devonian of Romania (Beju, 1967), and the Middle Devonian (Givetian) Hamilton Group in southern Ontario, Canada (Legault, 1971, Unpubl. Ph.D. Thesis). The stratigraphic range of this species is Silurian to lower Upper Devonian (Frasnian).

<u>REMARKS</u>: The Ghanaian specimens of this species are closely similar to the other specimens recorded elsewhere.

ANCYROCHITINA sp. cf. A. SPINOSA (Eisenack, 1932) Eisenack, 1959

Plate VIII, Figures 1-4

1932: <u>Conochitina</u> <u>spinosa</u> Eisenack, Paläont. Zeitschr., 14, p. 270, Pl. 12, figs. 11-13.

1959: <u>Ancyrochitina</u> <u>spinosa</u> (Eisenack), Eisenack, N. Jahrb. Geol. Paläont. Abh. 108, p. 18, Pl. 2, figs. 1, 2.

1959: <u>Ancyrochitina</u> <u>spinosa</u> (Eisenack), Dunn, Jour. Paleont. 33(6), p. 1013, Pl. 127, figs. 19-23.

1966: <u>Ancyrochitina</u> <u>spinosa</u> (Eisenack), Boekel, Dept. Nacional Prod. Min. Div. Geol. Min. 146, p. 10, Pl. III, fig. 7.

1970: <u>Ancyrochitina</u> cf. <u>A</u>. <u>spinosa</u> (Eisenack), Eisenack, Urban and Kline, Jour. Paleont. 44(1), p. 71, Pl. 18, figs. 1-3, 14.

1971: <u>Ancyrochitina</u> <u>spinosa</u> (Eisenack), Costa, An. Acad. Brasil, Ciênc., 43, p. 221, fig. 9.

1972: <u>Ancyrochitina</u> cf. <u>A</u>. <u>spinosa</u> (Eisenack) Eisenack, Urban, Bull. Amer. Paleont. 63(275), p. 11, Pl. 1, figs. 2, 3.

<u>DESCRIPTION</u>: Test medium size, flask shaped; body chamber high conical; neck short, cylindrical, about 1/3 of the total length of the test; flexure broad; shoulder absent; basal edge rounded to sub-rounded occasionally with long thick bifurcate or ramified basal processes, which are often broken off in many specimens; base convex; wall densely ornamented with simple and bifurcate spines 9.5-16 microns long and 3.1-4.2 microns diameter at the base; prosome plug-like within the neck or

absent in some specimens.

DIMENSIONS (in microns): 4 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	140-146	51-56	101-108	41-43	41-43
Mean:	145	53	106	42	42

ILLUSTRATED SPECIMENS:

Pl. VIII, fig. 1, Sample UC/19-2A/8290/4, Co-ordinate 116.4/38.0

Pl. VIII, fig. 2, Sample SE/10-1/8600/4, Co-ordinate 120.0/38.0

Pl. VIII, fig. 3, Sample UC/19-2A/9010/4, Co-ordinate 125.4/58.2

Pl. VIII, fig. 4, Sample UC/19-2A/9010/2, Co-ordinate 123.6/37.3

LOCALITY: This species occurs in all the three wells but is rare. (It is not indicated on the range charts).

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first described from Silurian sediments in the Baltic Region by Eisenack. The species has been observed from several Middle Devonian sediments in North America (Dunn, 1959; Urban and Kline, 1970; Urban, 1972), and South America (Boekel, 1966; Costa, 1971). The stratigraphic range of this species is Lower Silurian to Middle Devonian.

REMARKS: This species has general resemblance to *Ancyrochitina* sp. cf. *A.* sp. Jansonius which occurs commonly in the Ghanaian chitinozoan assemblage except that it has higher conical body chamber and somewhat longer cylindrical neck as compared with smaller size, lower conical body chamber and shorter flaring neck of *A.* sp. cf. *A.* sp. Jansonius.

ANCYROCHITINA sp. cf. A. DESMEA Eisenack, 1964

Plate IV, Figures 14-16

1964: Ancyrochitina desmea Eisenack N. Jahrb. Paläont., Abh., 120(3), p. 325, Pl. 29, fig. 3.

1967: Ancyrochitina cf. A. desmea Eisenack, Lange, Bol. Paranaense de Geociencias. 21/22, Pl. 1, figs. 4-6.

1971: Ancyrochitina desmea Eisenack, Costa, An. Acad. Brasil. Ciênc. 43, p. 218, fig. 3.

1971: Ancyrochitina cf. A. desmea Eisenack, Legault, Unpubl. Ph.D. Thesis, Univ. Oklahoma, p. 92, Pl. II, figs. 4-6.

DESCRIPTION: Test flask shaped; cylindro-conical; length of the neck about 1/3 total length of the test; flexure broad, distinct; shoulder absent; basal edge sharp; base convex; basal processes thick, ramified and bent in the direction of the oral pole; similar ramified processes occur on the neck, just a little below the edge of the lip; wall smooth; prosome, short, plug-like at the base of the neck.

DIMENSIONS (in microns): 5 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	124-186	33-66	93-106	40-41	40-42
Mean:	155	50	100	41	41

ILLUSTRATED SPECIMENS:

Pl. IV, figs. 14, 15, Sample SE/10-1/8500/3, Co-ordinate 124.7/2 .6

Pl. IV, fig. 16, Sample SE/10-1/8850/2, Co-ordinate 125.2/70.5

LOCALITY: This species is rare; a few specimens were observed in the

SE/10-1 well and the A-1 well.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first described from Silurian sediments in the Baltic Region by Eisenack. The species has been reported from the Middle Devonian of Brazil (Lange, 1967; Costa, 1971), and from the Middle Devonian Hamilton Group in southern Ontario, Canada (Legault, 1971). The stratigraphic range of this species is Lower Silurian to Middle Devonian.

REMARKS: The characteristic features of this species as described by Eisenack are the strong, antler-like ramified appendages around the basal periphery, which generally are bent in the oral direction and also similar strongly ramified appendages about the neck. These characterstics of *A. desmea* were observed in the Ghanaian specimens; however, the appendages on the neck of the Ghanaian specimens are located just a little below the tip of the lip or the upper portion of the neck, rather than at the mid-length of the neck.

Some specimens of *Ancyrochitina* sp. cf. *A. ancyrea* observed in the Ghanaian samples have similar ramified appendages. But the appendages on the basal edge (basal processes) of these specimens are usually bent downwards aborally rather than are bent in the oral direction. Besides, the appendages of *A.* sp. cf. *A. ancyrea* are located at the lip rather than at the mid-length of the neck.

ANCYROCHITINA TUMIDA Taugourdeau and Jekhowsky

Plate I, Figures 3, 4

Plate IV, Figure 13

1960: *Ancyrochitina tumida* Taugourdeau and Jekhowsky, Rev. Inst. Fr.

Pétrole XV(9), p. 1221, Pl. II, figs. 30, 31.

1971: Ancyrochitina cf. A. tumida Taugourdeau and Jekhowsky, Legault, Unpubl. Ph.D. Thesis, p. 103, Pl. IV, figs. 3-7.

DESCRIPTION: Test small with sub-globular body chamber and short, flaring neck about 1/3 total length of test; basal edge rounded with 4-6 anchor-like processes, 30-45 microns long and 4-8 microns maximum diameter; about four similar anchor-like spines occur at the edge of the lip; wall smooth; prosome not observed.

DIMENSIONS (in microns): 4 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	107-108	30-31	78-80	26-27	30-31
Mean:	108	31	80	26	31

ILLUSTRATED SPECIMENS:

Pl. I, figs. 3, 4, Sample UC/19-2A/8520

Pl. IV, fig. 13, Sample SE/10-1/8700/1, Co-ordinate 119.5/43.8

LOCATION: This species occurs in all the three wells but is rare

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was described from the Silurian to Middle Devonian of the Sahara (Taugourdeau and Jekhowsky, 1960). The species has also been reported from the Middle Devonian (Givetian) Hamilton Group in southern Ontario (Legault, 1971) Unpubl. Ph.D. Thesis).

ANCYROCHITINA sp. cf. A. sp. Jansonius, 1967

Plate VIII, Figures 5-19

Text-figure 15b

1967: Ancyrochitina sp. Jansonius, Rev. Palaeobot. Palynol., 1, p. 356, Pl. 1, figs. Q.R.

DESCRIPTION: Test small to medium size with conical body chamber and a short flaring neck, length of neck 1/4 - 1/5 total length of the test; flexure distinct; shoulder weakly developed or absent; basal edge rounded with a few bifurcating or simple spine-like processes which are usually broken off in many specimens observed; base convex; wall ornamented with thin, simple and bifurcate spines 6-16 microns long and 1.5-3.1 microns diameter at the base, occasionally spines are short and sparsely distributed on body; prosome, short, plug-like at the base of the neck or absent in some specimens.

DIMENSIONS (in microns): 20 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	97-124	20-25	84-87	28-35	37-47
Mean:	121	23	86	30	40

ILLUSTRATED SPECIMENS:

Pl. VIII, fig. 5, Sample UC/19-2A/8380/3, Co-ordinate 119.2/35.0

Pl. VIII, fig. 6, Sample UC/19-2A/9010/3, Co-ordinate 110.8/43.2

Pl. VIII, fig. 7, Sample A-1/1298-1300/4, Co-ordinate 120.3/44.8

Pl. VIII, fig. 8, Sample A-1/1298-1300/5, Co-ordinate 118.0/43.8

Pl. VIII, fig. 9, Sample UC/19-2A/8380/3, Co-ordinate 121.6/51.7

Pl. VIII, fig. 10, Sample UC/19-2A/8290/1, Co-ordinate 115.5/32.7

Pl. VIII, fig. 11, Sample UC/19-2A/9010/3, Co-ordinate 120.9/27.8

Pl. VIII, fig. 12, Sample SE/10-1/9050/1, Co-ordinate 112.0/24.4

Pl. VIII, fig. 13, Sample SE/10-1/8220/5, Co-ordinate 117.0/26.5

Pl. VIII, fig. 14, Sample UC/19-2A/8380/3, Co-ordinate 119.2/35.0

Pl. VIII, fig. 15, Sample SE/10-1/8300/4, Co-ordinate 125.0/33.6

Pl. VIII, fig. 16, Sample SE/10-1/8300/5, Co-ordinate 119.2/30.2

Pl. VIII, fig. 17, Sample A-1/1298-1300/1, Co-ordinate 122.0/39.0

Pl. VIII, fig. 18, Sample A-1/1298-1300/4, Co-ordinate 110.0/38.7

Pl. VIII, fig. 19, Sample SE/10-1/9000/5, Co-ordinate 122.8/26.5

LOCALITY: This species occurs in all the three wells studied. In UC/19-2A well, the species occurs commonly within the interval 8,290-8,450 feet depth, in the SE/10-1 well the species occurs rather sparingly at various depths. Only a few specimens of the species were observed in the A-1 well.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was recorded from Frasnian sediments (Hay River, Northwest Territories, Canada) by Jansonius (1967).

REMARKS: This species differs from *Ancyrochitina spinosa* Eisenack by its smaller size, lower conical body chamber and usually rapidly flaring necks. The Ghanaian specimens have similarity in shape of the test to the Canadian specimens but have less spinose ornamentation as compared with the Canadian specimens. The species appears to be generally similar to an undescribed *Ancyrochitina* sp. figured by Taugourdeau (1966, Pl. II, fig. 27) from the Frasnian of the Sahara.

?ANCYROCHITINA sp. cf. A. AEQUORIS Urban and Kline, 1970

Plate X, Figures 14-17

1970: Ancyrochitina aequoris Urban and Kline, Jour. Paleont., 44 (1) p.71, Pl. 18, figs. 6-9, 15-17.

DESCRIPTION: Test medium size; body chamber sub-cylindrical to sub-conical with maximum diameter at the basal edge and slightly tapering in the oral direction; neck cylindrical, about 1/3-1/4 total length of the test; flexure distinct; shoulder distinct; basal edge sub-rounded, base convex; wall ornamented with flattened spines parallel to oral-aboral axis, spines are simple, bifurcate and multifurcate, length of spines 8.0-16.4 microns, maximum diameter 4.6-6.2 microns at the base, spines may be vertically aligned or randomly distributed; prosome plug-like within the neck.

DIMENSIONS (in microns): 20 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	143-161	31-56	84-90	37-44	37-44
Mean:	155	43	85	40	40

ILLUSTRATED SPECIMENS:

Pl. X, fig. 14; Sample A-1/1298-1300/3, Co-ordinate 114.8/32.9

Pl. X, fig. 15; Sample A-1/1286-1288/3, Co-ordinate 114.8/39.1

Pl. X, fig. 16, Sample A-1/1286-1288/2, Co-ordinate 119.7/38.7

Pl. X, fig. 17, Sample A-1/1522-1534/1, Co-ordinate 125.4/31.2

LOCALITY: This species occurs commonly at various sections in A-1 well. It was not observed from the other two wells.

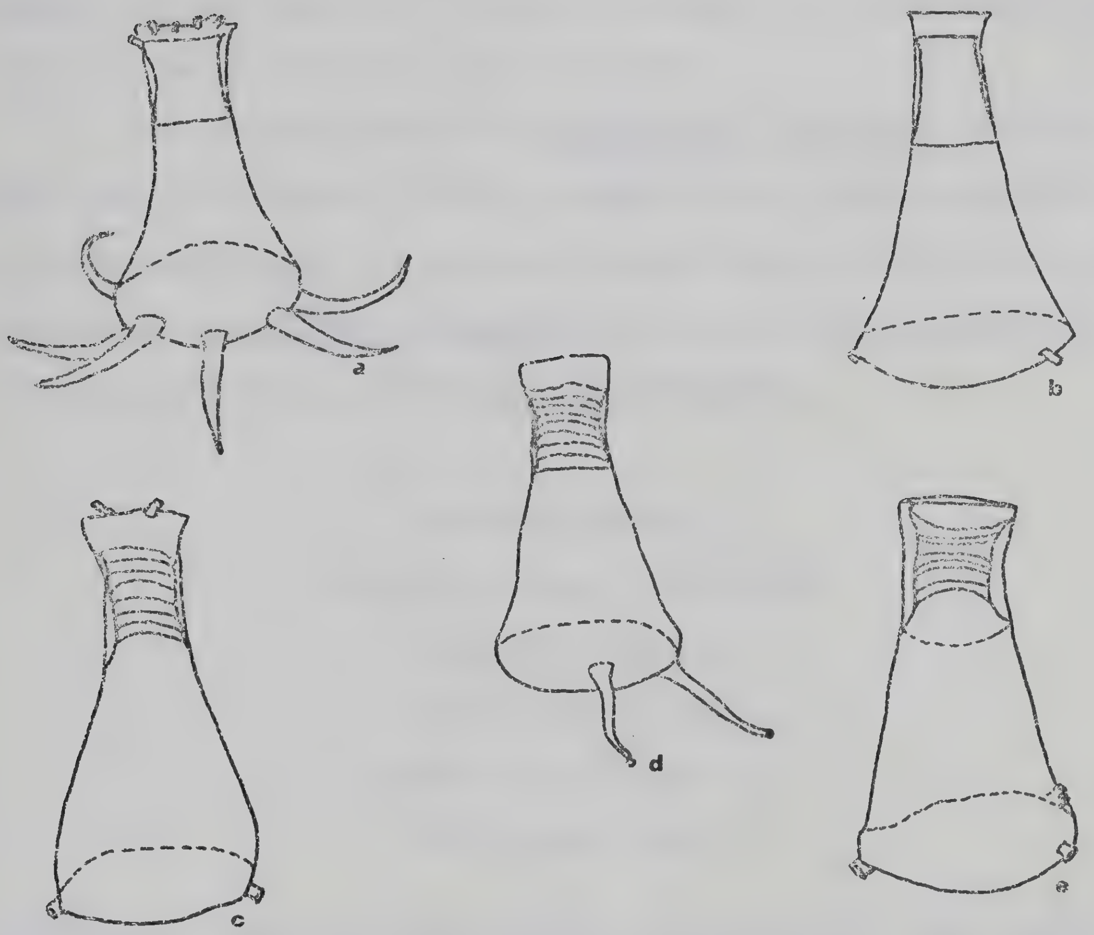

Figure 16a-e. Morphological Variation of *Ancyrochitina* sp. 1 from the Devonian of Ghana. (Semi-diagrammatic. Magnification of all illustrated specimens X300).

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was described from the Middle Devonian Cedar City Formation of Missouri by Urban and Kline (1970). The species appears restricted to the Middle Devonian.

REMARKS: The Ghanaian specimens of this species have much shorter necks compared with the Cedar City Formation specimens. The spine distribution of most of the Ghanaian specimens is random.

This species differs from *Angochitina callawayensis* Urban and Kline which also exhibits vertical alignment of the spine distribution, by its characteristic cylindro-conoid shape of the test and shorter necks. Specimens of *Angochitina callawayensis* observed from the Ghanaian sediments generally display simple and bifurcate spines.

ANCYROCHITINA sp. 1

Plate III, Figures 9-11; 14-18

Plate IV, Figure 6

Plate IX, Figures 9-16

Plate XVII, Figures 8, 9

Text-figures 16a-e

DESCRIPTION: Test medium size, elongate with high conical body chamber and very short neck from the body chamber but flared orally; flexure broad, indistinct; shoulder absent; basal edge sharp or occasionally rounded with six or less simple, long, tapering, spine-like basal processes which are usually lost in most of the specimens observed; base slightly convex; wall finely hispid to scaley, usually with distinct horizontal striations or growth lines (?), prosome short, plug-like at the base

of the neck, or annulated with a series of rings or discs within the neck.

DIMENSIONS (in microns): 20 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Pl. III, Fig. 17:	180	60(?)	99	31	36
Range:	145-185	14-57(?)	73-100	23-48	27-57
Mean:	167	34(?)	84	33	41

ILLUSTRATED SPECIMENS

Pl. III, fig. 9, Sample SE/10-1/8300/5, Co-ordinate 121.7/32.0

Pl. III, fig. 10, Sample SE/10-1/8300/3, Co-ordinate 118.5/37.2

Pl. III, fig. 11, Sample SE/10-1/8600/1, Co-ordinate 113.7/31.7

Pl. III, fig. 14, Sample SE/10-1/8600/4, Co-ordinate 123.0/35.2

Pl. III, fig. 15, Sample A-1/1298-1300/3, Co-ordinate 118.5/37.3

Pl. III, fig. 16, Sample A-1/1298-1300/3, Co-ordinate 125.5/31.7

Pl. III, fig. 17, Sample A-1/1298-1300/1, Co-ordinate 121.7/35.3

Pl. III, fig. 18, Sample SE/10-1/8300/5, Co-ordinate 114.8/45.6

Pl. IV, fig. 6, Sample UC/19-2A/8260/2, Co-ordinate 117.8/31.5

Pl. IX, fig. 10, Sample A-1/1404-1406/1, Co-ordinate 120.0/32.4

Pl. IX, fig. 11, Sample A-1/1298-1300/4, Co-ordinate 111.2/29.3

Pl. IX, fig. 12, Sample A-1/1318-1320/2, Co-ordinate 111.0/36.0

Pl. IX, fig. 13, Sample A-1/1450-1452/3, Co-ordinate 126.2/24.6

Pl. IX, fig. 14, Sample A-1/1298-1300/5, Co-ordinate 115.5/39.8

Pl. IX, fig. 15, Sample A-1/1298-1300/4, Co-ordinate 113.5/40.7

Pl. IX, fig. 16, Sample A-1/1318-1320/4, Co-ordinate 123.8/43.8

Pl. XVII, fig. 8, Sample A-1/1350-1352/1, Co-ordinate 125/3.39.8

Pl. XVII, fig. 9, Sample A-1/1522-1524/1, Co-ordinate 126.6/32.2

LOCALITY: This species forms one of the important components of the chitinozoan assemblage in the A-1 well. It was found from about 4,600 feet to the bottom of the well at about 5,000 feet depth. A few specimens of this species were also found in the SE/10-1 well between 8,300 feet to 8,850 feet depth, and between 8,260-8,350 feet depth in the UC/19-2A well.

REMARKS: This species has general similarity in the shape of the test to *Ancyrochitina striata* Taugourdeau but lacks the distinct folding of the test which is characteristic of *A. striata*.

ANCYROCHITINA sp. 2

Plate VI, Figures 1-8

Test-figure 14c-d

DESCRIPTION: Test flask shaped, cylindro-spheroid; neck, 1/3-1/2 total length of the test; six or less usually short, but variously shaped basal processes occur symmetrically around the lower hemisphere of the body chamber; these short basal processes may be chisel-shaped, clavate, bifurcated or long spine-like; lip may be slightly flared and ornamented by thin, short, simple spines; wall smooth; prosome probably short, plug-like at the base of the neck.

DIMENSIONS (in microns): 10 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Pl. VIII, fig. 2:	155	84	96	40	40
Range:	120-160	43-86	81-120	38-40	40-43
Mean:	150	64	95	39	42

LOCALITY: This species occurs commonly in all the three wells studied.

ILLUSTRATED SPECIMENS:

Pl. VI, fig. 1, Sample UC/19-2A/8770/1, Co-ordinate 118.0/44.8

Pl. VI, fig. 2, Sample UC/19-2A/9010/3, Co-ordinate 113.6/29.2

Pl. VI, fig. 3, Sample A-1/1488-1490/1, Co-ordinate 117.7/35.2

Pl. VI, fig. 4, Sample UC/19-2A/9010/4, Co-ordinate 123.3/49.6

Pl. VI, fig. 5, Sample UC/19-2A/8700/3, Co-ordinate 124.3/60.7

Pl. VI, fig. 6, Sample UC/19-2A/8350/2, Co-ordinate 114.2/69.5

Pl. VI, fig. 7, Sample SE/10-1/9050/2, Co-ordinate 116.7/60.2

Pl. VI, fig. 8, Sample SE/10-1/8700/2, Co-ordinate 111.0/54.0

REMARKS: The characteristic features of this species are the almost spherical body chamber and variously shaped basal processes symmetrically arranged near the lower hemisphere of the body chamber.

ANCYROCHITINA sp. 3

Plate VII, Figures 1-12, 14-15

DESCRIPTION: Test small; body chamber conical shaped; neck short and flaring, about 1/4 overall length of test; flexure broad, distinct;

shoulder absent or weakly developed; basal edge sharp or rounded usually with short spine-like basal processes or rarely multibranched basal processes; base convex; wall smooth; prosome, short, plug-like at the base of the neck or annulated with a series of circular discs within the neck.

DIMENSIONS (in microns): 20 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Pl. VII, fig. 1:	109	31	90	37	40
Range:	109-130	25-43	81-109	25-37	37-43
Mean:	115	31	96	34	40

ILLUSTRATED SPECIMENS:

Pl. VII, fig. 1, Sample UC/19-2A/8350/2, Co-ordinate 114.4/64.1

Pl. VII, fig. 2, Sample A-1/1350-1352/1, Co-ordinate 124.1/26.4

Pl. VII, fig. 3, Sample A-1/1450-1452/1, Co-ordinate 114.4/32.4

Pl. VII, fig. 4, Sample SE/10-1/8250/3, Co-ordinate 120.2/36.8

Pl. VII, fig. 5, Sample SE/10-1/8600/3, Co-ordinate 114.0/41.4

Pl. VII, fig. 6, Sample UC/19-2A/8880/3, Co-ordinate 112.4/23.0

Pl. VII, fig. 7, Sample A-1/1298-1300/2, Co-ordinate 117.2/37.6

Pl. VII, fig. 8, Sample SE/10-1/8400/2, Co-ordinate 114.2/34.2

Pl. VII, fig. 9, Sample SE/10-1/8250/5, Co-ordinate 114.8/31.8

Pl. VII, fig. 10, Sample SE/10-1/8250/6, Co-ordinate 118.7/42.4

Pl. VII, fig. 11, Sample SE/10-1/8300/5, Co-ordinate 120.0/29.2

Pl. VII, fig. 12, Sample SE/10-1/8600/3, Co-ordinate 126.0/35.4

Pl. VII, fig. 14, Sample SE/10-1/8350/2, Co-ordinate 120.7/25.0

Pl. VII, fig. 15, Sample UC/19-2A/8400/2, Co-ordinate 118.2/62.8

LOCALITY: This species is common in all the three wells studied.

REMARKS: This species is similar to *Ancyrochitina* sp. cf. *A.* sp. Jansonius in the shape of test, but differs from it by the absence of spinose ornamentation. Some specimens of *A.* sp. 3 show incipient folding of the wall while others show finely hispid ornamentation of the wall; these features are characteristic of *Ancyrochitina striata* and *Ancyrochitina* sp. 1, respectively. *Ancyrochitina striata* and *Ancyrochitina* sp. 1, however, are much larger in size and have much higher conical body chambers. *Ancyrochitina* sp. 3 also resembles some undescribed *Ancyrochitina* sp. figured by Taugourdeau (1966, Pl. I, fig. 5, Pl. II, fig. 37) from the Devonian of the Sahara.

? ANCYROCHITINA sp. 4

Plate VI, Figure 15

Text-figure 15e

DESCRIPTION: Test bottle shaped; chamber constricted at about the lower third of the test; neck short, flaring, about 1/6 the total length of the tests; flexure broad, indistinct; shoulder distinct; basal edge rounded with six or less thick, long, multibranched basal processes 20-30 microns long, 5-6 microns diameter at the base; similar but thinner spine-like processes occur at the constriction of the chamber and at the edge of the lip; wall thick, opaque, and smooth except at the ornamentation at the constriction and the lip; prosome not observed.

DIMENSIONS (in microns): 3 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Pl. VI, Fig. 15:	228	34	73	41	44
Range:	227-228	34	73-74	40-41	43-44
Mean:	228	34	73	41	44

ILLUSTRATED SPECIMEN:

Sample UC/19-2A/8500/6, Co-ordinate 119.4/43.0

LOCALITY: This species was observed in all the three wells studied but is rare.

ANCYROCHITINA sp. 5

Plate VII, Figures 13, 16, 17

DESCRIPTION: Test medium size, cylindro-conoid; length of neck, 1/2 the total length of the test; flexure broad and distinct; shoulder weakly developed; basal edge sharp with a few simple spine-like basal processes which are usually broken off; base convex, wall densely and uniformly ornamented with simple, short minute spines of less than two microns long; prosome, short plug-like within the neck, not observed in some specimens.

DIMENSIONS (in microns): One specimen measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Pl. VII, Fig. 13:	221	113	80	37	37

ILLUSTRATED SPECIMENS:

Pl. VII, fig. 13, Sample SE/10-1/8350/2, Co-ordinate 120.7/25.0

Pl. VII, fig. 16, Sample UC/19-2A;8700/3, Co-ordinate 124.7/60.6

Pl. VII, fig. 17, Sample UC/19-2A/8700/3, Co-ordinate 124.0/57.6

LOCALITY: This species occurs in the UC/19-2A well and the SE/10-1 well. It was not found in the A-1 well.

REMARKS: Most of the specimens of this species recovered from the two wells mentioned above were poorly preserved. The specimens have been assigned to the genus *Ancyrochitina* Eisenack by the conical body chamber, cylindrical neck and the seemingly long, spine-like basal processes (Pl. VII, fig. 16)

ANCYROCHITINA sp. 6

Plate V, Figures 8-11

Text-figure 15h

DESCRIPTION: Test bell-shaped; body chamber conical with an expanded base; neck cylindrical, 2/5 total length of the test, flared at the lip; neck-body chamber junction constricted; basal edge sharp, rounded with six or less simple long, tapering spine-like basal processes of about 37 microns long and 8 microns maximum diameter; base convex; wall smooth; lip thin and transparent; occasionally, long thin, simple spines occur at the lip; prosome short to elongate, plug-like, within the neck.

DIMENSIONS (in microns) 14 specimens measured:

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Pl. V, Fig. 8	205	81	96	43	56
Range:	155-205	62-81	93-96	34-43	47-48
Mean:	186	68	94	40	50

ILLUSTRATED SPECIMENS:

Pl. V, fig. 8, Sample UC/19-2A/8880/1, Co-ordinate 126.7/68.0

Pl. V, fig. 9, Sample UC/19-2A/9010/3, Co-ordinate 122.8/34.3

Pl. V, fig. 10, Sample A-1/1442-1444/1, Co-ordinate 117.5/44.2

Pl. V, fig. 11, Sample UC/19-2A/8900/4, Co-ordinate 114.6/58.4

LOCALITY: This species was observed from all the three wells.

REMARKS: This species is distinguished from *A. langei* Sommer and van Boekel by its bell shape and the distinct constriction between the neck and the body chamber.

ANCYROCHITINA sp. 7

Plate VI, Figures 12-14

Text-figures 14f-g

DESCRIPTION: Test medium size, flask shaped; body chamber conical; neck sub-cylindrical, short, about 1/3 total length of test, slightly flared at the lip; flexure very broad; basal edge broadly rounded with a few (six or less) long, thin, multifurcate basal processes; length of basal processes 50-65 microns, diameter of basal processes at the base 3.1-4.6

SPECIES / CHARACTERISTICS	TOTAL LENGTH (in microns)	NECK LENGTH (in microns)	CHAMBER DIAMETER (in microns)	NECK DIAMETER (in microns)	APERTURE DIAMETER (in microns)	SPINE LENGTH (in microns)	SPINE DIAMETER (in microns)	NECK LENGTH / TOTAL LENGTH	APICAL ANGLE (in degrees)	REMARKS
Ancyrochitina sp. cf. *A. ancyrea* Eisenack Pl. III, Figs. 1-8, 12, 13	124 - 180 (140)	34 - 93 (65)	84 - 112 (87)	25 - 50 (37)	25 - 50 (37)	-	-	0.45 - 0.52 (0.47)	44 - 75 (67)	Test cylindro-conical; neck well defined wall smooth; simple, bifurcate, ramified basal processes.
Ancyrochitina striata Taugourdeau Pl. IV, Figs. 1-5, 7, 8; Pl. XVII, Figs. 11, 12	130 - 180 (146)	37 - 46 (40)	70 - 96 (87)	28 - 56 (37)	26 - 44 (34)	-	-	0.29 - 0.43 (0.36)	37 - 65 (46)	Test high conical; wall folded along vertical axis of test.
Ancyrochitina sp. cf. *A. cornigera* Collinson & Scott Pl. IV, Figs. 9-12	124 - 205 (155)	31 - 50 (46)	78 - 90 (84)	31 - 43 (37)	35 - 47 (40)	-	-	0.25 - 0.3 (0.31)	27 - 40 (33)	Test high conical; short flaring neck; basal processes short, simple, tapering, straight or curved inwards.
Ancyrochitina langei Sommer & van Boekel Pl. V, Figs. 1-4	155 - 217 (201)	62 - 112 (84)	78 - 109 (84)	37 - 47 (43)	37 - 47 (43)	-	-	0.37 - 0.47 (0.41)	32 - 37 (34)	Test cylindro-conical; thick, long, simple basal processes; long, simple or occasionally bifurcate appendages on lip.
Ancyrochitina sp. cf. *A. gumersinda* Cramer Pl. V, Figs. 5-7	220 - 290 (244)	114 - 220 (159)	80 - 103 (93)	48 - 51 (50)	48 - 51 (50)	-	-	0.64 - 0.76 (0.70)	67 - 75 (71)	Test cylindro-conical; disproportionately long neck.
Ancyrochitina tomentosa Taug. & Jekh. Pl. VI, Figs. 9-11	135 - 189 (148)	43 - 85 (65)	73 - 97 (85)	37 - 45 (40)	43 - 47 (46)	11 - 28	3 - 10	0.39 - 0.55 (0.45)	48 - 75 (53)	Body chamber sub-globular; wall ornamented with thick, simple and bifurcate spines; basal process very prominent.
Ancyrochitina sp. cf. *A. spinosa* Eisenack Pl. VIII, Figs. 1-4	140 - 146 (145)	51 - 56 (53)	101 - 108 (106)	41 - 43 (42)	41 - 40 (42)	9 - 16	3 - 4	0.25 - 0.39 (0.32)	40 - 76 (61)	Test cylindro-conical; wall ornamented with thin, simple and bifurcate spines.
Ancyrochitina sp. cf. *A. desmea* Eisenack Pl. IV, Figs. 14-16	124 - 186 (155)	33 - 66 (50)	93 - 106 (100)	40 - 41 (41)	40 - 42 (41)		-	0.26 - 0.36 (0.33)	60 - 65 (60)	Test cylindro-conical; broad flexure; basal processes thick, ramified and bent in the direction of oral pole.
Ancyrochitina tumida Taug. & Jekh. Pl. IV, Fig. 13	107 - 108 (108)	30 - 31 (30)	78 - 80 (80)	26 - 27 (26)	30 - 31 (31)	-	-	0.17	60 - 70 (65)	Body chamber sub-globular; neck short flaring; anchor-like appendages on lip and basal edge.
Ancyrochitina sp. cf. *A.* sp. Jansonius Pl. VIII, Figs. 5-19	97 - 124 (121)	20 - 25 (23)	84 - 87 (85)	28 - 32 (30)	37 - 47 (40)	9 - 16	3 - 10	0.16 - 0.23 (0.20)	45 - 60 (53)	Test short and flaring neck; wall ornamented with simple and bifurcate spines.
Ancyrochitina sp. 1. Pl. III, Figs. 9-11, 14-18; Pl. IV, Fig. 6; Pl.IX,Figs.9-16; Pl.XVII,Figs.8,9	149 - 177 (163)	14 - 57 (34)	73 - 100 (84)	23 - 48 (33)	27 - 57 (41)	-	-	0.08 - 0.32 (0.21)	21 - 64 (36)	Test high conical; neck short, usually flaring; wall hispid to finely scaley.
Ancyrochitina sp. 2. Pl. VI, Figs. 1-8	120 - 160 (150)	43 - 86 (64)	81 - 120 (95)	38 - 40 (39)	40 - 43 (42)	-	-	0.38 - 0.54 (0.43)	-	Test cylindro-spheroid; basal processes varied; smooth wall.
Ancyrochitina sp. 3. Pl. VII, Figs 1-12, 14-15(?)	109 - 130 (115)	25 - 43 (31)	81 - 109 (96)	25 - 37 (34)	37 - 47 (40)	-	-	0.21 - 0.35 (0.26)	48 - 70 (65)	Test short and flaring neck; wall smooth.
?*Ancyrochitina* sp. 4. Pl. VI, Fig. 15	228	34	73	40	43	20 - 30	5 - 6	0.19	27 - 30 (28)	Test bottle shaped; chamber constricted at the mid-portion; basal process thick ramified spines at constriction at mid-portion.
Ancyrochitina sp. 5. Pl. VII, Figs. 13, 16, 17.	221	113	80	37	37	<2	<1	0.57	32 - 44 (38)	Test cylindro-conical; wall uniformly ornamented with minute spines.
Ancyrochitina sp. 6. Pl.V, Figs. 8-11	155 - 205 (186)	62 - 81 (68)	93 - 96 (94)	34 - 43 (40)	47 - 48 (50)	-	-	0.31 - 0.40 (0.37)	30 - 32 (31)	Test bell shaped; body chamber broad at base; distinct constriction between body chamber and neck.
Ancyrochitina sp. 7. Pl. V, Figs. 12-14	149 - 177 (163)	47 - 65 (56)	99 - 118 (109)	34 - 46 (40)	37 - 49 (43)	12 - 20	1.2 - 1.6	0.32 - 0.37 (0.35)	46 - 50 (48)	Test cylindro-conical with broad rounded base; long, thin multibranched basal process; long thin simple, multifurcate spines on neck and upper part of body chamber.

Table 7. Summary of Measurements in Various Species of *Ancyrochitina* from the Devonian of Ghana. (Figures in parenthesis are means.)

microns; base convex; wall ornamented with thin, simple bifurcate spines of about 12-20 microns long and 1.2-1.6 microns maximum diameter, these spines are densely distributed on neck and lip, and are sparsely distributed on body chamber; prosome plug-like within the neck.

DIMENSIONS (in microns): 2 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Pl. V, Fig. 13	149	47	99	34	37
Pl. V, Fig. 12	177	65	118	46	49

ILLUSTRATED SPECIMENS:

Pl. V, Fig. 13, Sample SE/10-1/8700/1, Co-ordinate 118.5/66.3

Pl. V, Fig. 12, Sample SE/10-1/8700/1, Co-ordinate 117.8/45.0

LOCALITY: A few specimens of this species were found only from the SE/10-1 well. The species was not observed from the other wells.

REMARKS: This species differs from Ancyrochitina tomentosa Taugourdeau by its thin, long, and multifurcate basal processes and densely distributed multibranched spines on the body, especially on the neck and lip. The species appears to be similar to "Complex" of Ancyrochitina ancyrea Eisenack, (1931), figured by Cramer (1973, Pl. 2, figs. 3, 4, 5, 11) from the Middle and Upper Silurian, Florida, U.S.A.

Genus ANGOCHITINA Eisenack, 1931

Type species: Angochitina echinata Eisenack, 1931

DIAGNOSIS: Test small to medium size; body chamber oval to subrounded;

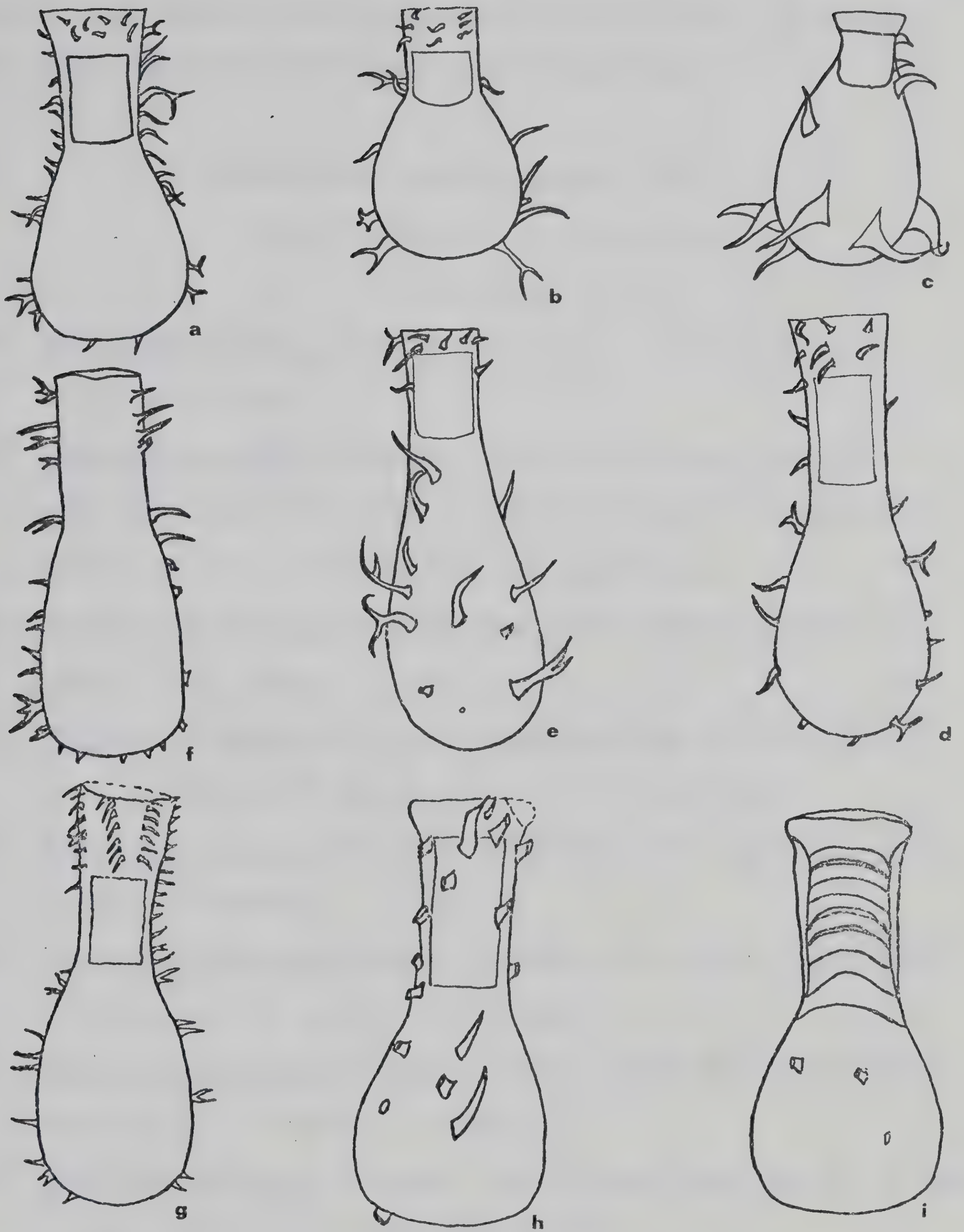

Figure 17. Morphological Variability of some *Angochitina* spp. from the Devonian of Ghana. (Semi-diagrammatic. Magnification of all illustrated specimens X300). 17a-b, *Angochitina devonica* Eisenack; 16c. *Angochitina* sp. cf. *A. devonica* Eisenack; 17d-e, *Angochitina* sp. cf. *A. devonica* Eisenack; 17f, *Angochitina* sp. cf. *A. ramosi* (Sommer and van Boekel); 17g, *Angochitina* sp. 1; 17h-i, *Angochitina* sp. 2.

neck well differentiated; flexure broad; shoulder and basal edge inconspicuous; base rounded, wall ornamented with numerous small to medium spines which may occasionally occur near the aperture.

ANGOCHITINA DEVONICA Eisenack, 1955

Plate X, Figures 1-3, 6-10,11(?)

Text-figures 17a-b

1955: Angochitina devonica Eisenack, Senck, leth. 36 (5/6), p. 318, Pl. 1, figs. 10-12.

1958: Angochitina devonica Eisenack, Collinson and Scott, Illinois State Geol. Surv. Circ. 247, p. 13, Pl. 1, figs. 6, 9, 10, 14, 18, 20, 21, 24, Pl. 3, figs. 22, 24, 26, text-fig. 4.

1959: Angochitina devonica Eisenack, Dunn, Jour. Paleont. 33 (6), p. 1010, Pl. 125, figs. 1, 2, 4-8.

1960: Angochitina devonica Eisenack, Taugourdeau and Jekhowsky, Rev. Inst. Fr. Pétrole XV (9), p. 1221, Pl. 3, figs. 36, 37.

1962: Angochitina devonica Eisenack, Taugourdeau, Rev. Micropaléo. 4 (4), p. 232 (not figured).

1964: Angochitina devonica Eisenack, Doubinger, Bull. Serv. Carte Géol. Als. Lorr. 16 (4), p. 262, Pl. 1, figs. 1, 2, 5.

1964: Angochitina devonica Eisenack, Grignani and Mantovani, Rev. Micropaléo. 6 (4), p. 245, Pl. 1, fig. 14.

1964: Angochitina devonica Eisenack, Cramer, Leidse Geol. Med. 30, p. 340, Pl. XX, figs. 2, 3, Pl. XXI, figs. 18-20.

1964: Angochitina devonica Eisenack, Doubinger and Poucet, C. R. Soc. Géol. France 1964 (3), p. 104, fig. d.

1966: Angochitina devonica Eisenack, Taugourdeau, Soc. Geol. France, Mem. 104, p. 32, 50, Pl. 2, figs. 38, 53.

1967: Angochitina devonica Eisenack, Lange, Bol. Paranaeuse Geociências 21/22, p. 72, Pl. 2, figs. 14-16.

1967: Angochitina devonica Eisenack, Beju, Rev. Palaeobot. Palynol., 5 (1-4), p. 45, Pl. II, figs. 9, 10.

1971: Angochitina devonica Eisenack, Costa, An. Acad. Brasil. Ciênc., 43, p. 225, (Fig. 17).

1971: Angochitina devonica Eisenack, Legault, Unpubl. Ph. D. Thesis, p. 10, Pl. VI, figs. 3-5.

1972: Angochitina devonica Eisenack, Urban, Bull. Amer. Paleont. 63 (275), p. 14, Pl. 2, figs. 1-12, text-fig. 3a.

DESCRIPTION: Test flask shaped with globular or ovoid body chamber and cylindrical neck about 1/2 or less of the overall length of test; wall ornamented with numerous simple and bifurcate spines; prosome short and plug-like or occasionally long and annulated with circular discs.

DIMENSIONS (in microns): 20 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	130-188	31-85	68-96	31-50	31-50
Mean:	153	50	81	40	41

ILLUSTRATED SPECIMENS:

Pl. X, fig. 1, Sample UC/19-2A/8250/2, Co-ordinate 122.0/30.7

Pl. X, fig. 2, Sample SE/10-1/8700/1, Co-ordinate 119.5/54.9

Pl. X, fig. 3, Sample A-1/1298-1300/5, Co-ordinate 111.2/41.2

Pl. X, fig. 6, Sample SE/10-1/8300/4, Co-ordinate 109.7/29.6

Pl. X, fig. 7, Sample SE/10-1/8300/1, Co-ordinate L 110.3/35.4

Pl. X, fig. 8, Sample SE/10-1/8300/2, Co-ordinate 116.6/28.2

Pl. X, fig. 9, Sample SE/10-1/8300/3, Co-ordinate 108.3/31.5

Pl. X, fig. 10, Sample SE/10-1/8300/1, Co-ordinate L 110.3/35.4

Pl. X, fig. 11, Sample SE/10-1/8300/6, Co-ordinate 123.0/32.0

LOCALITY: This species forms one of the important components of the chitinozoan assemblage in all the three wells studied.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species has been recorded from various Devonian sediments in Europe, North Africa, North America and South America. The stratigraphic range of the species is Upper Silurian to Upper Devonian.

REMARKS: The characteristic flask-shaped test and the long, simple and bifurcate spines all over the body make this species easy to identify.

ANGOCHITINA sp. cf. A. DEVONICA Eisenack, 1955

Plate X, Figures 4, 5

Text-figures 17e-d

REMARKS: This species is a variant of *A. devonica*. Its flexure is very broad and its body chamber-neck junction is not well defined, ornamentation consists of simple and bifurcate spines 20-35 microns long, and 3.0-6.5 microns maximum diameter; prosome long, plug-like with incipient annulation.

DIMENSIONS (in microns): 5 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	223-232	87-93	78-81	40-43	40-53
Mean:	227	92	80	42	45

ILLUSTRATED SPECIMENS:

Pl. X, fig. 4, Sample A-1/1460-1462/1, Co-ordinate 118.5/41.6

Pl. X, fig. 5, Sample A-1/1224-1226/3, Co-ordinate 109.5/38.9

LOCALITY: This species was observed from A-1 well only.

ANGOCHITINA CALLAWAYENSIS Urban and Kline, 1970

Plate X, Figures 12, 13

1970: Angochitina callawayensis Urban and Kline, Jour. Paleont. 44 (1), p. 72, Pl. 18, figs. 11, 12, 18-22.

DESCRIPTION: Test medium size, cylindro-ovoid; length of neck 1/3-2/5 total length of the test; flexure broad, distinct; shoulder weakly developed; base convex; wall ornamented with simple and bifurcate spines arranged in rows extending from the aboral pole to the oral pole, but near the shoulder two rows of spines appear to converge to a point to form a single row which then continues from the flexure to the oral edge; prosome absent in some specimens but when present appears opaque and plug-like within the neck.

DIMENSIONS (in microns): 10 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	150-177	43-62	71-85	31-43	31-43
Mean:	164	50	81	40	40

ILLUSTRATED SPECIMENS:

Pl. X, fig. 12, Sample A-1/1286-1288/2, Co-ordinate 111.5/37.1

Pl. X, fig. 13, Sample A-1/1286-1288/2, Co-ordinate 120.5/36.8

LOCALITY: This species was found only from the A-1 well within the interval 4,160-4,270 feet depth.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species has been described from the Middle Devonian Cedar City Formation of Missouri by Urban and Kline (1970). It appears to be restricted to the Middle Devonian.

REMARKS: The Ghanaian specimens of this species are similar to the Cedar City Formation specimens in the distribution of the spines in rows along the oral-aboral axis of the test.

ANGOCHITINA sp. cf. A. CAPILLATA Eisenack, 1937

Plate XI, Figures 4-6, 8-12, 15 (?)

1937: Angochitina capillata Eisenack, Paläont. Z, 19(3/4), p. 255, Pl. 15, figs. 12, 13.

1959: Angochitina capillata Eisenack, Dunn, Jour. Paleont. 33 (6), p. 1012, Pl. 126, figs. 12, 13, 15, 16.

1962: Angochitina capillata Eisenack, Beju and Danet, Petrol şi Gaze, 12, p. 530, Pl. 1, fig. 18, 19.

1964: Angochitina cf. capillata Eisenack, Grignani and Mantovani, Rev. Micropaléo. 6 (4), p. 244, Pl. 1, figs. 7-10.

1965: Angochitina capillata Eisenack, N. Jb. Geol. Paläeont. Abh. 123 (2), p. 122, Pl. II, fig. 3.

1966: Angochitina capillata Eisenack, Taugourdeau, Soc. Géol. France, Mem. 104, p. 33, 50, Pl. 1, fig. 17, Pl. 2, fig. 40.

1967: Angochitina cf. A. capillata Eisenack, Lange, Bol. Paranaeuse Geociências 21/22, p. 72, Pl. 2, figs. 14-16.

1969: Angochitina capillata Eisenack, Jenkins, Spec. Paper Palaeont. 5, p. 10, Pl. 1, figs. 7-13.

1971: Angochitina capillata Eisenack, Costa, An. Acad. Brasil. Ciênc., 43, p. 223, (Fig. 15).

1972: Angochitina capillata Eisenack, Urban, Bull. Amer. Paleont. 63, (275), p. 15, Pl. 3, fig. 8.

DESCRIPTION: Test flask shaped with sub-globular body chamber and cylindrical neck about 1/3 of the overall length, slightly flared at the lip; wall ornamented with simple, sharp-pointed spines, which diminish in size towards the lip where they are much reduced or absent; the spines on the body are occasionally eroded; prosome, short, plug-like or incipiently annulated.

DIMENSIONS (in microns): 10 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	164-202	47-78	87-102	43-53	43-62
Mean:	183	50	93	50	52

ILLUSTRATED SPECIMENS:

Pl. XI, fig. 4, Sample SE/10-1/8000/1, Co-ordinate 116.1/33.8

Pl. XI, fig. 5, Sample UC/19-2A/8700/1, Co-ordinate 120.7/50.0

Pl. XI, fig. 6, Sample UC/19-2A/8310/1, Co-ordinate 46.7/117.8

Pl. XI, fig. 8, Sample UC/19-2A/8700/2, Co-ordinate 123.0/30.4

Pl. XI, fig. 9, Sample UC/19-2A/8700/1, Co-ordinate 118.5/48.6

Pl. XI, fig. 11, Sample UC/19-2A/8950/2, Co-ordinate 124.8/43.6

Pl. XI, fig. 12, Sample UC/19-2A/8700/2, Co-ordinate 126.4/53.5

LOCALITY: This species occurs commonly in the UC/19-2A well. A few specimens were also observed in the SE/10-1 well. The species was not found from the A-1 well.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species has been recorded from Ordovician-Devonian sediments in Europe and North America, Lower to Upper Devonian in South America and Upper Devonian in North Africa.

REMARKS: This species differs from *Angochitina globosa* Collinson and Scott, described from the Middle Devonian Cedar Valley Formation, Illinois, by its sharp pointed simple spines which may be completely absent at the lip. *Angochitina mourai* Lange has more globose body chamber with simple and bifurcating spines which may be interconnected at the base.

ANGOCHITINA MOURAI Lange, 1952

Plate XI, Figure 13, 17

Plate XIII, Figures 1-5

Plate XVII, Figure 6

1952: *Angochitina mourai* Lange, Dusenia III (5), p. 377-379, Pl. XVIII,

fig. 7-9, Pl. XIX, figs. 10-12.

1958: Angochitina mourai Lange, Collinson and Scott, Illinois State Geol. Surv. Circ. 247, p. 16, text-fig. 7, Pl. fig. 16, Pl. 3, fig. 11.

1959: Angochitina mourai Lange, Dunn, Jour. Palaeont. 33(6), p. 1012, Pl. 125, figs. 9, 11.

1964: Angochitina mourai Lange, Grignani and Mantovani, Rev. Micropaléo. 6 (4), p. 245, Pl. figs. 19, 20.

1967: Angochitina mourai Lange, Boekel, Atlas do Simpósio sôbre a Biota Amazônica, 1, p. 98, Pl. 1, fig. 6.

1967: Angochitina mourai Lange,Lange, Bol. Paranaense, Geociências 21/22, p. 74, Pl. 2, figs. 17-20.

19 : Angochitina mourai Lange, Costa, An. Acad. Brasil. Ciênc., 43, p. 227, (Fig. 21).

DESCRIPTION: Test cylindro-spherical; length of neck 1/3-1/4 total length of the test; wall ornamented with fine to fairly coarse simple and bifurcating spines, or occasionally long and thin spines distributed randomly all over the body; spines on most of the specimens observed were eroded; prosome plug-like within the neck.

DIMENSIONS (in microns): 20 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	146-192	47-68	87-106	40-56	40-65
Mean:	165	57	96	47	50

ILLUSTRATED SPECIMENS:

Pl. XI, fig. 13, Sample SE/10-1/8220/3, Co-ordinate 115.3/41.5

Pl. XI, fig. 17, Sample UC/19-2A/8700/1, Co-ordinate 124.3/41.0

Pl. XIII, fig. 1, Sample SE/10-1/8220/3, Co-ordinate 113.0/40.5

Pl. XIII, fig. 2, Sample SE/10-1/8220/4, Co-ordinate 116.0/34.6

Pl. XIII, fig. 3, Sample SE/10-1/8220/1, Co-ordinate 118.5/38.7

Pl. XIII, fig. 4, Sample SE/10-1/8220/3, Co-ordinate 120.5/40.3

Pl. XIII, fig. 5, Sample A-1/1226-1228/2, Co-ordinate 120.8/36.8

LOCALITY: This species occurs commonly in all the three wells studied.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species occurs commonly in Middle and Upper Devonian sediments in Brazil from where it was first described. According to Costa (1971) the stratigraphic range of the species is Silurian-Upper Devonian. Grignani and Montovani (1964) recorded the species from the Upper Devonian of Morocco. A few specimens of the species have also been found from the Middle Devonian Cedar Valley Formation of Illinois (Collinson and Scott, 1958), and from the same formation in Iowa (Dunn, 1959).

ANGOCHITINA (RAMOCHITINA) RAMOSI (Sommer and van Boekel, 1964)

Plate XII, Figures 1, 2, 6-17

1964: Ramochitina ramosi Sommer and van Boekel, An. Acad. Brasil. Ciênc. 36 (4), p. 426, Pl. I, fig. 3, Pl. II, figs. 3, 4, text-fig. 3.

1967: Ramochitina ramosi Sommer and van Boekel, Lange, Bol. Paranaense Geociências 21/22, p. 81, Pl. 4, figs. 37, 38.

1971: Ramochitina ramosi Sommer and van Boekel, Costa, An. Acad. Brasil.

Ciênc., 43, p. 255, (Fig. 74).

DISCUSSION: Sommer and van Boekel (1964) proposed the genus Ramochitina with R. ramosi being the type species for chitinozoans with the following characteristics (translation in Lange, 1967, p. 81):

> "Cylindric-ovoid shape, the principal character being the spines which branch repeatedly and cover all the body surface; prosome quite conspicuous; body chamber ellipsoid; neck conoid; collar short."

The characteristics of Ramochitina ramosi Sommer and van Boekel as translated by Lange (op. cit.) are as follows:

> "Specimens, cylindro-ovoid, lengthened, amber coloured, with a more or less transparent test. Body chamber occupies 3/4 of overall length, being ellipsoid of form with convex base. Flexure not very conspicuous making it difficult to establish separation of the body chamber-neck. Neck conoid, collar short. Prosome distinct, about 35 microns long. Many thin and repeatedly branched spines, situated all over the body. Overall length of holotype: 220 microns."

Lange (op. cit.) indicated that several hundred specimens of this species he observed in the Paraná Basin, Brazil "... agree in general with the original diagnosis, although in addition to the cylindro-ovoid shape, some specimens present somewhat more expanded, ovate chambers. Furthermore, ... not all the appendages are branched, many of the specimens display an association of branched and simple pointed appendages on the chambers, and smaller, simple to bifid spines on the neck ..."

In the Ghanaian Devonian sediments, chitinozoans with similar characteristics described above were observed and a large number of these specimens have been illustrated to show the various variations in the shape of the test and the spinose ornamentation.

It appears that chitinozoans with the above characteristics belong to the genus Angochitina Eisenack, 1931. Jansonius (1970, p. 797) has suggested that the genus Ramochitina should be transferred to the genus Angochitina Eisenack, 1931.

DIMENSIONS (in microns): 20 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	161-220	37-62	71-81	28-37	34-44
Mean:	192	48	75	34	37

ILLUSTRATED SPECIMENS:

Pl. XII, fig. 1, Sample UC/19-2A/8290/2, Co-ordinate 125.5/47.2

Pl. XII, fig. 2, Sample UC/19-2A/8310/4, Co-ordinate 118.5/36.1

Pl. XII, fig. 6, 7, Sample A-1/1298-1300/3, Co-ordinate L111.4/47.8

Pl. XII, fig. 8, Sample A-1/1350-1352/1, Co-ordinate 120.6/44.0

Pl. XII, fig. 9, Sample A-1/1450-1452/1, Co-ordinate 121.6/31.4

Pl. XII, fig. 10, Sample A-1/1460-1462/1, Co-ordinate 121.4/32.2

Pl. XII, fig. 11, Sample A-1/1298-1300/3, Co-ordinate 111.7/31.4

Pl. XII, fig. 12, Sample A-1/1266-1268/2, Co-ordinate 111.4/28.4

Pl. XII, fig. 13, Sample A-1/1298-1300/5, Co-ordinate 110.4/46.4

Pl. XII, fig. 14, Sample A-1/1298-1300/4, Co-ordinate 114.5/28.3

Pl. XII, fig. 15, Sample A-1/1298-1300/1, Co-ordinate 120.1/19.1

Pl. XII, fig. 16, Sample A-1/1298-1300/1, Co-ordinate 122.3/43.6

Pl. XII, fig. 17, Sample A-1/1266-1268/3, Co-ordinate 125.5/25.0

LOCALITY: This species occurs most commonly in the A-1 well. It was also observed from the other two wells.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species is restricted to the Lower-Middle Devonian in Brazil.

ANGOCHITINA (RAMOCHITINA) MAGNIFICA (Lange, 1967)

Plate XVII, Figure 15

1967: *Ramochitina magnifica* Lange, Bol. Paranaense Geociências 21/22, p. 83, Pl. 4, figs. 39-45, Pl. 5, figs. 46-51.

1971: *Ramochitina magnifica* Lange, Costa, An. Acad. Brasil. Ciênc. 43, p. 255, fig. 73.

DESCRIPTION: Test flask shaped with an ovate body chamber and a short cylindrical neck, length of neck about 1/3 total length of the vesicle; wall ornamented with broad, ramified, interconnected processes; prosome not observed.

DIMENSIONS (in microns): 1 specimen measured.

Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
167	53	96	50	50

ILLUSTRATED SPECIMEN:

Sample SE/10-1/8450/1, Co-ordinate 116.0/49.5

LOCALITY: Only one specimen of this species was found in the SE/10-1 well at 8,450 feet depth.

OCCURRENCE AND STRATIGRAPHIC RANGE: Lower Devonian, Brazil.

REMARKS: The size range of the Brazilian specimens of this species is

255-380 microns. The only specimen found in Ghana is 167 microns in length, but the shape of the test and the ornamentation of the Ghanaian specimen are closely similar to the Brazilian specimens.

ANGOCHITINA COMOSA Taugourdeau and Jekhowsky, 1960

Plate XIII, Figure 12

1960: Angochitina comosa Taugourdeau and Jekhowsky, Rev. Inst. Fr. Pétrol 15 (9), p. 1221, figs. 33, 34, 35.

1964: Angochitina comosa Taugourdeau and Jekhowsky, Grignani and Mantovani, Rev. Micropaléo 4(4), p. 245, Pl. 1, fig. 11.

DESCRIPTION: Test medium size, flask shaped with an ovoid body chamber and a sub-cylindrical neck about 2/5 the total length of the test; lip slightly flared; wall ornamented with coarse spines but mostly eroded off; prosome annulated within the neck.

DIMENSIONS (in microns): 4 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	180-186	65-70	78-80	48-50	58-60
Mean:	184	66	79	49	59

ILLUSTRATED SPECIMEN:

Sample SE/10-1/8220/1, Co-ordinate 125.3/18.7.

LOCALITY: This species occurs restricted to 8,220 feet depth in the SE/10-1 well. It was not observed from the two other wells.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first described from the Lower to Middle Devonian in the Sahara (Taugourdeau and Jekhowsky, 1960). Grignani and Mantovani (1964) reported the species from the Middle to Upper Devonian in the Sahara.

REMARKS: The Ghanaian specimens of this species are similar to the North African specimens.

ANGOCHITINA sp. cf. A. COMOSA Taugourdeau and Jekhowsky, 1960

Plate XIII, Figure 8

REMARKS: This species is essentially similar to *A. comosa* Taugourdeau and Jekhowsky by the shape of the test and spinose ornamentation, but the neck is shorter and gradually flaring.

DIMENSIONS (in microns): 5 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	160-174	48-60	78-82	48-50	60-62
Mean:	163	53	80	49	61

ILLUSTRATED SPECIMEN:

Pl. XIII, fig. 8, Sample SE/10-1/8000/1, Co-ordinate 109.3/38.7

LOCALITY: This species was observed from the SE/10-1 well but very rare.

ANGOCHITINA sp. cf. A. BIFURCATA Collinson and Schwalb

Plate XI, Figures 10, 14

1955: *Angochitina bifurcata* Collinson and Schwalb, Illinois State Geol. Surv. Rept. 186, p. 21, Pl. 2, figs. 1-3, text-fig. 7.

1971: *Angochitina bifurcata* Collinson and Schwalb, Costa, An. Acad. Brasil. Ciênc., 43, p. 224, (Fig. 14).

DESCRIPTION: Test medium size, flask shaped; body chamber ovoid; neck short, 1/4 - 1/3 total length of the test; wall ornamented with sparsely distributed bifurcate spines 12-15 microns long, and 4.8-5.1 microns diameter at the base; prosome short and plug-like, or annulated into series of rings or discs within the neck.

DIMENSIONS (in microns): 8 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	171-183	60-62	74-78	37-47	37-47
Mean:	177	61	76	42	42

ILLUSTRATED SPECIMENS:

Pl. XI, fig. 10, Sample UC/19-2A/8400/1, Co-ordinate L112.0/25.6

Pl. XI, fig. 14, Sample UC/19-2A/8700/3, Co-ordinate 120.2/68.4

LOCALITY: This species occurs sparingly in the UC/19-2A well and the

SE/10-1 well. It was not observed from the A-1 well.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first described from the Lower Devonian Bailey Formation of southern Illinois by Collinson and Schwalb (1955). The species has also been reported from the Middle Devonian of Brazil (Costa, 1971).

REMARKS: The Ghanaian specimens of this species have shorter necks and sparse distribution of the spines. The bifurcated nature of the spines is, however, very characteristic.

ANGOCHITINA sp. cf. A. CRUMENA Taugourdeau, 1962

Plate XVI, Figure 11

1962: *Angochitina crumena* Taugourdeau, Rev. Micropaléo., 4(4), p. 232, Pl. 1, figs. 12-13.

1964: *Angochitina crumena* Taugourdeau, Grignani and Mantovani, Rev. Micropaléo., 6(4), p. 245, Pl. 1, figs. 12, 13.

1971: *Angochitina crumena* Taugourdeau, Costa, An, Acad, Brasil. Ciênc., 43, p. 225, (Fig. 16).

DESCRIPTION: Test medium size, flask shaped with a sub-globular body chamber and a short neck about 1/5-1/4 total length of the test, neck flared at the lip; wall ornamented with coarse, simple spines 10-16 microns long and 2-5 microns wide at the base, randomly and sparsely distributed all over the body; prosome plug-like within the neck.

DIMENSIONS (in microns): 10 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	155-205	31-50	78-93	43-56	56-68
Mean:	176	45	81	50	62

ILLUSTRATED SPECIMEN:

Sample SE/10-1/800/4, Co-ordinate 124.9/29.7

LOCALITY: This species was found only from the SE/10-1 well at 8,000 feet depth.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first recorded from the Famennian(?) of the Sahara (Taugourdeau, 1962). Grignani and Mantovani (1964) also recorded the species from Upper Devonian sediments in Morocco. The species has also been observed in Lower Silurian and Upper Devonian sediments in Brazil (Costa, 1971). The stratigraphic range of this species is Lower Silurian-Upper Devonian.

REMARKS: *Angochitina crumena* as diagnosed by Taugourdeau (*op. cit.*) has spherical body chamber and a short neck about 1/5 the total length of the body. The Ghanaian specimens have sub-globular body chamber and short and distinctly flaring necks.

ANGOCHITINA sp. cf. A. LONGICOLLA Eisenack, 1959

Plate XVII, Fig. 5

1959: *Angochitina longicolla* Eisenack, N. Jb. Geol. Palaeont., Abh., 108, p. 13, Pl. 2, figs. 8-9.

1964: *Angochitina longicolla* Eisenack, Taugourdeau and Jekhowsky, Rev. Inst. Fr. Pétrole XIX (7-8), p. 857, Pl. 1, figs. 1-7.

1966: Angochitina cf. longicolla Eisenack, Taugourdeau, Mem. Soc. Géol. France 104, Pl. II, fig. 42.

DESCRIPTION: Test medium size with sub-globular body chamber and a long cylindrical neck about 3/5 total length of the test; wall ornamented with short spines 6.2 microns high and 4.7 microns wide. These ornaments occur commonly on the neck and the lip and appear to be partly eroded from the body chamber; prosome, short, annulated at the base of the neck.

DIMENSIONS (in microns): 1 specimen measured.

Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
214	127	78	37	50

ILLUSTRATED SPECIMEN:

Sample SE/10-1/8750/1, Co-ordinate 121.8/46.2

LOCALITY: Only one specimen of this species was found from the SE/10-1 well at 8,750 feet depth.

ANGOCHITINA sp. 1

Plate XII, Figures 3-5

Text-figure 16g

DESCRIPTION: Test medium size with ovoid body chamber and a distinct sub-cylindrical neck, about 2/5 the total length of the test, neck slightly flared orally; wall ornamented with simple and bifurcate spines of 14-17 microns long and 2.1-3.2 microns maximum diameter; spines on upper half of neck distinctly aligned in vertical rows of six or less, spines on

lower half of neck and chamber body randomly distributed; prosome, dark, plug-like within the neck.

DIMENSIONS (in microns): 2 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Pl. XII, fig. 3:	210	80	83	37	45
Pl. XII, fig. 4a:	210	85	78	37	48

ILLUSTRATED SPECIMENS:

Pl. XII, fig. 3, Sample UC/19-2A/8600/1, Co-ordinate 122.4/32.6

Pl. XII, figs. 4a, b, Sample SE/10-1/8700/1, Co-ordinate 127.3/31.8

LOCALITY: This species is very rare. One specimen was found in the UC/19-2A well and the other in the SE/10-1 well.

REMARKS: This species has much longer neck than *Angochitina ramosi* (Sommer and van Boekel). Another distinguishing characteristic is the distinct vertical rows of spines restricted to the upper half of the neck. *Angochitina callawayensis* Urban and Kline has simple, bifurcate or multifurcate spines arranged in rows extending from the aboral pole to the oral end.

ANGOCHITINA sp. 2

Plate XI, Figure 7

Plate XIII, Figures 14

Text-figures 16h-i

DESCRIPTION: Test flask shaped; body chamber sub-conical with a flat

base; neck cylindrical, flared at the lip, length of neck about 1/2 total length of the test; wall ornamented with simple, thick, coarse spines 15-25 microns long and 3.1-6.4 microns maximum diameter; when spines are completely abraded wall appears smooth; prosome long and plug-like or long and annulated within the neck.

DIMENSIONS (in microns): 2 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Pl. XI, fig. 7	220	100	99	47	62
Pl. XIII, fig. 14	202	98	93	50	68

ILLUSTRATED SPECIMENS:

Pl. XI, fig. 7, Sample UC/19-2A/8880/4, Co-ordinate 119.9/26.4

Pl. XIII, fig. 14, Sample SE/10-1/8000/5, Co-ordinate 120.5/37.2

LOCALITY: This species occurs sparingly in the SE/10-1 well. Only one specimen was found from the UC/19-2A well at 8,880 feet depth. The species was not observed from the A-1 well.

REMARKS: This species has general similarity in the shape of the test to Haplochitina oumdoulensis described by Grignani and Mantovani (1964) from the Devonian of Morocco. H. oumdoulensis is, however, smooth and has no spinose ornamentation.

ANGOCHITINA sp. 3

Plate XIII, Figures 6, 7

DESCRIPTION: Test medium size; body chamber ellipsoid to ovoid with a

short cylindrical neck about 1/2-1/3 the total length of the test; wall densely covered with small, simple spines 2.0-3.0 microns long and 1.0 microns maximum diameter at the base; prosome plug-like within the neck.

DIMENSIONS (in microns): 5 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Pl. XVIII, Fig. 7:	217	50	90	44	44
Range:	186-220	47-52	90-96	43-50	43-50
Mean:	208	50	92	44	44

ILLUSTRATED SPECIMENS:

Pl. XIII, Fig. 6, Sample SE/10-1/8220/5, Co-ordinate 116.0/32.8

Pl. XIII, Fig. 7, Sample SE/10-1/8220/5, Co-ordinate 121.0/32.8

LOCALITY: This species is restricted to 8,220 feet depth in the SE/10-1 well. It was not observed in the two other wells.

ANGOCHITINA sp. 4

Plate XI, Figures 1, 2

DESCRIPTION: Test medium size, club-shaped; body chamber sub-cylindrical or ovoid; neck cylindrical about 2/5 total length of test; flexure distinct; shoulder distinct; basal edge rounded; base rounded to sub-rounded; wall densely ornamented with simple small spines towards the neck and the lip; prosome absent.

SPECIES / CHARACTERISTICS	TOTAL LENGTH (in microns)	NECK LENGTH (in microns)	CHAMBER DIAMETER (in microns)	NECK DIAMETER (in microns)	APERTURE DIAMETER (in microns)	SPINE LENGTH (in microns)	SPINE DIAMETER (in microns)	NECK LENGTH / TOTAL LENGTH	REMARKS
Angochitina devonica Eisenack Pl. X, Figs. 1 – 3, 6 – 11	130 – 188 (153)	31 – 85 (50)	68 – 96 (81)	31 – 50 (40)	31 – 50 41	15 – 28	< 4	0.33 – 0.42 (0.37)	Test cylindro-globoid; spines simple and bifurcate.
Angochitina sp. c f. *A. aevonica* Eisenack Pl. X, Figs. 4 – 5	223 – 232 (227)	87 – 93 (92)	78 – 81 (80)	40 – 43 (42)	40 – 53 (45)	28 – 31	< 6	0.44 – 0.46 (0.33)	Test elongated large, ovoid; flexure weakly developed; spines simple and bifurcate.
Angochitina callawayensis Urban & Kline Pl. X, Figs. 12, 13	150 – 177 (164)	43 – 62 (50)	71 – 85 (81)	31 – 43 (40)	31 – 43 (40)	15 – 19	< 4	0.30 – 0.38 (0.33)	Test cylindro-ovoid; spines simple or bifurcate arranged in vertical rows; two rows of spines converge at shoulder and continue orally as single row.
Angochitina sp. cf. *A. capillata* Eisenack Pl. XI Figs. 4 – 6, 8 – 12, 15	164 – 202 (183)	47 – 78 (50)	87 – 102 (93)	43 – 53 (50)	43 – 62 (52)	6 – 10	< 2	0.26 – 0.28 (0.27)	Test flask shaped; spines simple, sharp-pointed, much reduced or absent on the lip.
Angochitina mourai Lange Pl. XI, Figs. 13, 17, Pl. XIII, Figs. 1-5, Pl. XVII, Fig. 6	146 – 192 (165)	47 – 68 (57)	87 – 106 (96)	40 – 56 (47)	40 – 65 (50)	6 – 30	< 3	0.31 – 0.36 (0.34)	Test cylindro-spherical; spines fine to fairly coarse, simple and bifurcating, randomly distributed.
Angochitina (Ramochitina) ramosi Sommer & van Boekel Pl. XII, Figs. 1, 2, 6 – 17	161 – 220 (192)	37 – 62 (48)	71 – 81 (75)	28 – 37 (34)	34 – 44 37	30 – 32	< 4	0.24 – 0.26 (0.24)	Test cylindro-ovoid to ellipsoid; spines simple, bifurcate, multifurcate.
Angochitina (Ramochitina) magnifica Lange Pl. XVII, Fig. 15	167	53	96	50	50	40	< 15	0.32	Test cylindro-ovoid, ornamented with broad, interconnected processes or spines.
Angochitina comosa Taugourdeau Pl. XIII, Fig. 12	180 – 186 (184)	65 – 70 (66)	78 – 80 (79)	48 – 50 (49)	58 – 60 59	10	< 4	0.41 – 0.45 (0.43)	Test cylindro-ovoid; neck long and flaring spines coarse, mostly eroded.
Angochitina sp. cf. *A. bifurcata* Collinson & Schwalb Pl. XI, Figs. 10, 14	171 – 183 (177)	60 – 62 61	74 – 78 (76)	37 – 47 (42)	37 – 47 (42)	12 – 15	< 5	0.34 – 0.35 (0.35)	Test flask shaped; spines bifurcate, sparsely distributed.
Angochitina sp. cf. *A. crumena* Taugourdeau Pl. XVI, Fig. 11	155 – 205 (176)	31 – 50 (45)	78 – 93 (81)	43 – 56 (50)	56 – 68 (62)	10 – 16	< 5	0.20 – 0.25 (0.23)	Test flask shaped with sub-globular body chamber and short flaring necks; spines simple.
Angochitina sp. cf. *A. longicolla* Eisenack Pl. XVII, Fig. 5	214	127	78	37	50	> 16	< 6	0.6	Test cylindro-globular, neck long; spines simple.
Angochitina sp. sp. 1 Pl. XII, Figs. 3 – 4	210 – 210 (210)	80 – 85 (83)	78 – 83 (78)	37 – 37 (37)	45 – 48 (47)	14 – 17	< 4	0.38 – 0.40 (0.39)	Test cylindro-ovoid; spines simple and bifurcate, spines on upper half of neck arranged in rows; spines on body randomly distributed.
Angochitina sp. 2 Pl. XVIII, Fig. 14; Pl. XIII, Fig. 14	202 – 220 (211)	93 – 100 (97)	93 – 99 (96)	47 – 50 (48)	62 – 68 (65)	15 – 25	< 7	0.46 – .47 0.46	Test flask shaped; body chamber sub-conical with a flat base; neck flared at the lip; spines coarse, simple.
Angochitina sp. 3 Pl. XIII, Figs. 6, 7	186 – 220 (208)	47 – 52 (50)	90 – 96 (92)	43 – 50 (44)	43 – 50 (44)	2 – 3	< 1	0.25 – 27 (0.26)	Test cylindro-ovoid to cylindro-ellipsoid; spine, simple, minute, densely distributed.
Angochitina sp. 4 Pl. XI, Figs. 1, 2	222 – 263 (243)	77 – 100 (89)	83 – 83 (83)	40 – 46 (43)	46 – 46 (46)	8 – 10	< 2	0.36 – 0.38 0.37	Test club-shaped; body chamber sub-cylindrical to ovoid; spines simple, small, densely distributed.

Table 8. Summary of Measurements in Various Species of *Angochitina* from the Devonian of Ghana. (Figures in parentheses are means.)

DIMENSIONS (in microns): 2 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Pl. XI, Fig. 1:	263	100	83	46	46
Pl. XI, Fig. 2:	222	77	83	40	40

ILLUSTRATED SPECIMENS:

Pl. XI, fig. 1, Sample A-1/1266-1268/1, Co-ordinate 117.4/34.4

Pl. XI, fig. 2, Sample UC/19-2A/8350/2, Co-ordinate 115.3/61.5

LOCALITY: This species is very rare; only the illustrated specimens were observed, one from the A-1 well at 4,844 feet and the other from UC/19-2A well at 8,350 feet depth.

Genus CLADOCHITINA Lange, 1967

Type species: Cladochitina biconstricta (Lange, 1949) Lange, 1967.

DIAGNOSIS: Chitinozoa with conical body chamber and expanded basal margin with slightly convex base; neck cylindrical, 1/3-1/2 overall length of test, expanded at the lip; flexure distinct; shoulder indistinct; scattered coarse spines occur on basal edge and body, smaller spines sometimes attached laterally to the lip; prosome short, plug-like, to elongate and annulated.

CLADOCHITINA VARISPINOSA Lange, 1967

Plate IX, Figures 1-9

Text-figure 18

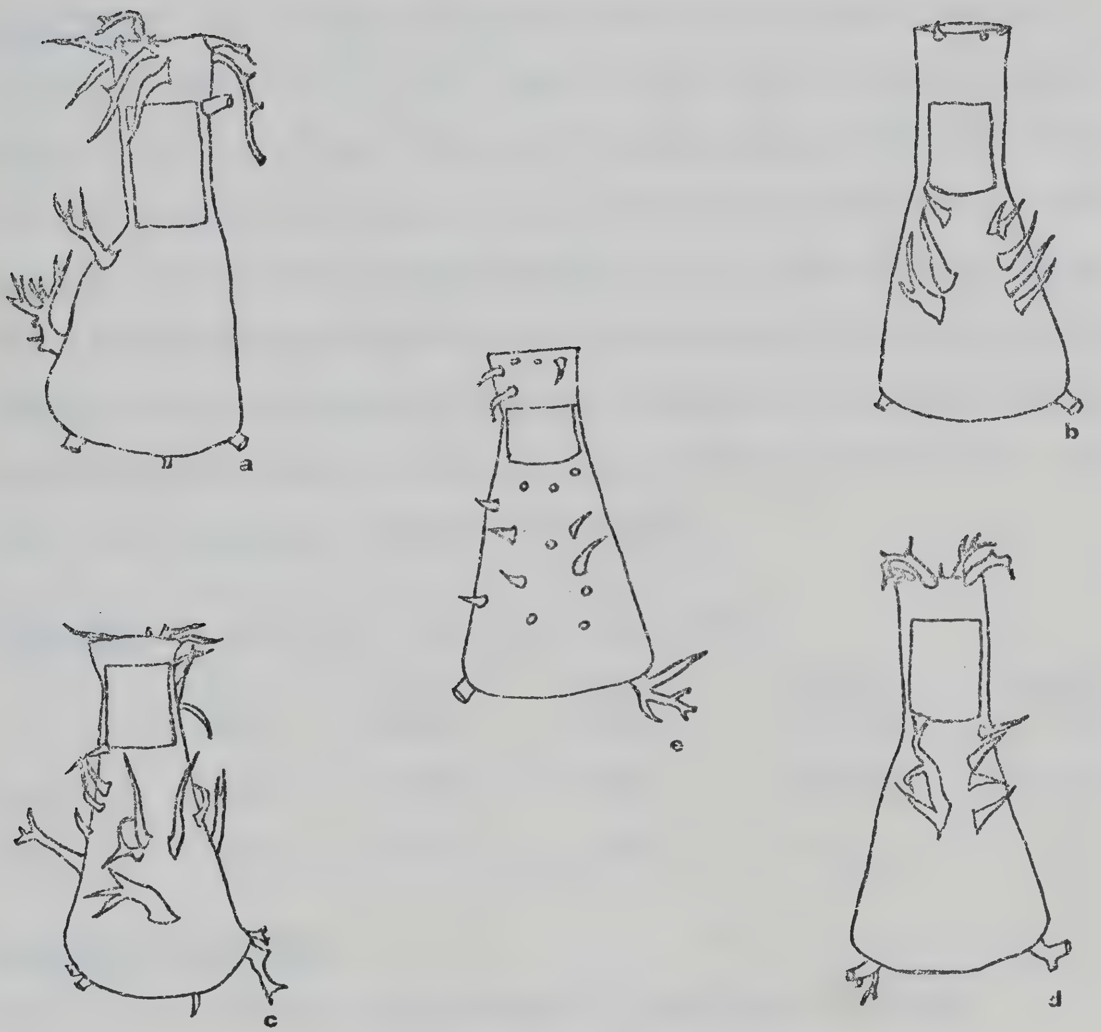

Figure 18a-d. Morphological Variation of *Cladochitina varispinosa* Lange from the Devonian of Ghana. (Semi-diagrammatic. Magnification of all illustrated specimens X300).

1967: Cladochitina varispinosa Lange, Bol. Paranaense Geociências 21/22, p. 78, Pl. 2, figs. 27-35.

1971: Cladochitina varispinosa Lange, Costa, An. Acad. Brasil, Ciênc., p. 228, (Fig. 23).

DESCRIPTION: Test elongate with high conical body chamber and short, cylindrical neck, 1/4-2/5 total length of the test, neck occasionally flared at the lip; flexure distinct; shoulder absent; basal edge sharp with thick, long, multibranched basal processes, 30 microns more or less long and about 8 microns maximum diameter; wall ornamented with coarse, thick, simple and multibranched spines 20-30 microns long and 5-7 microns diameter; long, thin spines 20-30 microns long, and 6-7 microns diameter also occasionally occur at the periphery of the lip; prosome dark, short, plug-like or somewhat elongated and expanded.

DIMENSIONS (in microns): 20 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	152-217	37-90	68-96	31-47	37-53
Mean:	180	56	86	38	44

ILLUSTRATED SPECIMENS:

Pl. IX, fig. 1, Sample UC/19-2A/8500/4, Co-ordinate 115.9/33.3

Pl. IX, fig. 2, Sample UC/19-2A/8500/4, Co-ordinate 115.9/33.3

Pl. IX, fig. 3, Sample UC/19-2A/8650/2, Co-ordinate 125.8/25.7

Pl. IX, fig. 4, Sample UC/19-2A/8650/2, Co-ordinate 114.4/65.5

Pl. IX, fig. 5, Sample UC/19-2A/8650/1, Co-ordinate 117.7/50.6

Pl. IX, figs. 6, 7, Sample UC/19-2A/8550/1, Co-ordinate 124.6/35.5

Pl. IX, fig. 8, Sample UC/19-2A/8650/2, Co-ordinate 114.6/59.3

Pl. IX, fig. 9, Sample UC/19-2A/8600/2, Co-ordinate 118.0/26.0

LOCALITY: This species occurs in all the three wells but most commonly in the UC/19-2A well.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species occurs restricted to the Middle Devonian (Eifelian?), Brazil, from where it was first described by Lange (1967).

REMARKS: The Ghanaian specimens of this species are essentially similar to the Brazilian specimens in the ornamentation of the test which varies from thick, short, simple spines to long bifurcate and multibranched spines. The Ghanaian specimens, however, have shorter necks and are generally smaller than the Brazilian specimens. The overall length of the Ghanaian specimens ranges between 150-217 microns as compared with 167-374 microns recorded for the Brazilian specimens.

Genus CONOCHITINA Eisenack, 1931

Type species: *Conochitina claviformis* Eisenack, 1931.

DIAGNOSIS: Test medium to large, conical, with cylindrical neck; basal edge rounded; base flat to convex.

?CONOCHITINA sp. 1

Plate XVII, Fig. 10

DESCRIPTION: Test small, with conical shaped body chamber and short, indistinct neck; basal edge sharp; base flat; wall ornamented with short,

blunt spines or granules 1.5-2.2 microns high and 1.5-3.1 microns wide, these ornaments occur on all parts of the body including the base; prosome short, plug-like within the neck.

DIMENSIONS (in microns): 1 specimen measured

Total Length	Neck Length	Chamber Diameter	Aperture Diameter
84	?	74	31

ILLUSTRATED SPECIMEN:

Sample UC/19-2A/7060/1, Co-ordinate 120.1/58.5

LOCALITY: Only the figured specimen of this species was found from the UC/19-2A well at 7,060 feet depth.

?CONOCHITINA sp. 2

Plate XVII, Figure 14

DESCRIPTION: Test cylindro-conical; length of neck about 2/5 the total length of the test; flexure broad, distinct; shoulder weakly developed; basal edge rounded, base flat; wall ornamented with sparsely distributed, long, thin spines 6.8-10.3 microns long and 2.0-2.2 microns wide at the base; most of the spines are broken off but their grapnel endings are quite distinct; prosome plug-like within the neck.

DIMENSIONS (in microns): 1 specimen measured.

Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
140	56	76	40	40

ILLUSTRATED SPECIMENS:

Sample UC/19-2A/7060/2, Co-ordinate 124.0/48.5

LOCALITY: Only the figured specimen of this species was found from the UC/19-2A well at 7,060 feet depth.

REMARKS: This species differs from ?*Conochitina* sp. 1 by its distinct neck and sparse distribution of the spine-ornamentation.

?CONOCHITINA sp. 3

Plate XI, Figure 16

DESCRIPTION: Test medium size, cylindro-conoid; body chamber conical; neck cylindrical, about 1/3 total length of test; basal edge sharp, acute; base convex; wall ornamented with minute spines; prosome plug-like within the neck.

DIMENSIONS (in microns): One specimen measured:

Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
146	62	93	40	40

ILLUSTRATED SPECIMEN:

Sample UC/19-2A/8400/1, Co-ordinate 127.7/65.8

LOCALITY: This species is very rare; only two specimens were observed, one from UC/19-2A well and the other from A-1 well.

?CONOCHITINA sp. 4

Plate XVII, Figure 7

DESCRIPTION: Test medium size; body chamber sub-cylindrical with straight sides; neck short about 1/4 total length of test; flexure distinct, shoulder present, basal edge rounded; base convex; wall ornamented with thick, blunt and curved spines arranged in a series of vertical rows along the vertical axis of the test, spine length 4-5 microns long and 3-4 microns diameter at the base; prosome plug-like within the neck.

DIMENSIONS (in microns): One specimen measured:

Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
152	47	81	40	37

ILLUSTRATED SPECIMENS:

Sample UC19-2A/400/2, Co-ordinate L110/2/23.4.

LOCALITY: Only the figured specimen was observed from the UC/19-2A well at 8,400 feet depth.

?CONOCHITINA sp. 5

Plate XVII, Figures 13, 16

Text-figure 19b

DESCRIPTION: Test cylindro-conical; body chamber conical shaped; neck about 1/2 the total length of test; flexure broad and distinct, shoulder weakly developed; basal edge rounded; base flat; wall sparsely ornamented with simple spines of less than 1.0 microns long and 0.4 - 0.5 microns

diameter; at the basal edge, however, a few large spines about 21.7 microns long and 6.4 microns maximum diameter may occur; prosome plug-like and somewhat annulated within the upper portion of the neck.

DIMENSIONS (in microns): 2 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Pl. XVII, Fig. 13:	229	109	99	53	56
Pl. XVII, Fig. 16:	264	124	96	50	50

ILLUSTRATED SPECIMENS:

Pl. XVII, Fig. 13, Sample UC/19-2A/8480/1, Co-ordinate 115.7/29.1

Pl. XVII, Fig. 16, Sample A-1/1442-1444/3, Co-ordinate 109.5/30.5

LOCALITY: Only the figured specimens were observed, from the UC/19-2A well at 8,480 feet depth and the other from the A-1 well at about 4,765 feet depth.

Genus DESMOCHITINA Eisenack, 1931

Type species: *Desmochitina nodosa* Eisenack, 1931

DIAGNOSIS: Test small, body sub-spherical to barrel shaped; neck absent, lip more or less flaring; operculum simple, external; many species show tendency to form chains.

DESMOCHITINA sp.

Plate XVIII, Figure 4

DESCRIPTION: Test spherical to ovoid shaped; wall opaque rough textured;

operculum not observed; occurs in chains.

DIMENSIONS (in microns): 5 specimens (figured measured) measured.

	Maximum Diameter	Minimum Diameter
Range:	104-114	78-106
Mean:	110	89

ILLUSTRATED SPECIMENS:

Sample SE/10-1/8450/2, Co-ordinate 121.0/55.6

LOCALITY: This species is rare; only the figured specimens were found from section 8,450 feet depth in the SE/10-1 well.

REMARKS: This species is somewhat similar to *Desmochitina sphaerica* described by Taugourdeau and Jekhowsky from the Silurian of the Sahara. *D. sphaerica* is smaller and more spherical than the Ghanaian specimens.

Genus EISENACKITINA Jansonius, 1964

Type species: *Eisenackitina castor* Jansonius, 1964.

DIAGNOSIS: Vesicle sub-cylindrical; basal edge more or less distinct; base flat or convex; sides straight, more or less parallel; greatest width near the basal edge, lower part of the body chamber sometimes bulging; no flexure, shoulder usually not apparent; neck or lip very much reduced, usually absent, but cuticle near aperture often thins abruptly; aperture simple, smooth, with a diameter significantly smaller than that of the vesicle at the shoulder; operculum external, but usually not raised above the shoulders; it may have concentric structure and car-

ries a short thin membrane; cuticle smooth, roughened or verrucose, occasionally with a few small spines.

EISENACKITINA sp. 1

Plate XVIII, Figures 12, 13

Text-figure 19c

DESCRIPTION: Test sub-cylindrical with maximum diameter at the base and gradually tapering orally; neck very much reduced to a narrow flange or absent; flexure absent; shoulder absent; basal edge rounded; base slightly convex; wall thick, rough textured; operculum disc-like, external, usually lost in most specimens.

DIMENSIONS (in microns): 10 specimens measured.

	Total Length	Chamber Diameter	Aperture Diameter	Operculum Diameter
Pl. XVIII, Fig. 13:	161	135	99	65
Range:	161-192	135-149	87-99	--
Mean:	175	140	93	--

ILLUSTRATED SPECIMENS:

Pl. XVIII, Fig. 12, Sample A-1/1336-1338/3, Co-ordinate 115.6/43.8

Pl. XVIII, Fig. 13, Sample A-1/1318-1320/4, Co-ordinate 114.3/41.3

LOCALITY: This species occurs sparingly in the Atiavi-1 well. It was not observed from the other two wells.

REMARKS: This species differs from *Eisenackitina castor* described from

the Middle Devonian, Northwest Territories, Canada (Jansonius, 1964) by its broader, seemingly thick body wall and lack of any ornamentation.

Genus FUNGOCHITINA Taugourdeau, 1966

Type species: Fungochitina fungiformis Taugourdeau, 1966

DIAGNOSIS: Test medium size, with a long cylindrical neck and a short conical body chamber, length of body chamber less than half total length; base flat, prosome probably elongate.

FUNGOCHITINA sp. cf. F.LONGICOLLIS (Taugourdeau and Jekhowsky) Taugourdeau, 1966

Plate XVII, Figure 1

1960: Sphaerochitina longicollis Taugourdeau and Jekhowsky, Rev. Inst. Fr. Pétrole, XV(9), p. 1231, Pl. X, figs. 145, 146, Pl. XI, fig. 163.

1962: Sphaerochitina longicollis Taugourdeau and Jekhowsky, Rev. Micropaléo., 4(4), p. 234, Pl. 1, figs. 20, 21.

1966: Fungochitina longicollis (Taugourdeau and Jekhowsky) Taugourdeau, Rev. Micropaléo., 9(4), Pl. 1, fig. 21.

DESCRIPTION: Test medium size with a sub-globular body chamber and a disproportionately long cylindrical neck, length of neck 4/5 total length of test; wall opaque, somewhat smooth; prosome not observed.

DIMENSION (in microns): 1 specimen measured.

Total Length	Neck Length	Chamber Diameter	Neck Diameter
434	326	87	44

ILLUSTRATED SPECIMEN:

Sample UC/19-2A/9010/5, Co-ordinate 115.8/65.3

LOCALITY: This species is very rare; only the figured specimen was found from the UC/19-2A well at 9,010 feet deep.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species has been recorded from the Lower Devonian in the Sahara (Taugourdeau and Jekhowsky, 1960).

FUNGOCHITINA sp. cf. F. PISTILLIFORMIS LATA (Taugourdeau and Jekhowsky)

Plate XVII, Fig. 2

1960: Sphaerochitina pistilliformis lata Taugourdeau and Jekhowsky, Rev. Inst. Fr. Petrolé, XV(9), p. 1232, Pl. XI, figs. 156, 157.

1966: Fungochitina pistilliformis lata (Taugourdeau and Jekhowsky) Taugourdeau, Mem. Soc. Géol. France, Pl. 1, fig. 6, 7.

DESCRIPTION: Test medium size, with short, discoid-like body chamber and a disproportionately long cylindrical neck, length of neck about 4/5 total length of the vesicle, slightly flared at the aperture; wall semi-opaque dark brownish, somewhat smooth; prosome not observed.

DIMENSION (in micron): 1 specimen measured.

Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
189	146	87	31	43

ILLUSTRATED SPECIMEN:

Sample SE/10-1/8850/1, Co-ordinate 125.5/31.2

LOCALITY: This species is very rare; only the figured specimen was

found in the SE/10-1 well at 8,850 feet depth.

OCCURRENCE AND STRATIGRPHIC RANGE: This species has been recorded from the Silurian of the Sahara (Taugourdeau and Jekhowsky, 1960, 1962).

REMARKS: The only specimen found from the Ghanaian sediments was too poorly preserved to allow any definite comparisons. However, the Ghanaian specimen of this species has a sub-globular body chamber and a convex base as compared with the somewhat flat base characteristic of the Saharan specimens.

FUNGOCHITINA sp. 1

Plate XVII, Figs. 3, 4

DESCRIPTION: Test medium size, elongate with short, discoid body chamber and disproportionately long tapering neck which may flare at the lip; length of neck about 3/4 total length of the test, wall thin, smooth, wrinkled; prosome long, annulated within the neck but may be absent.

DIMENSIONS (in microns): Two specimens measured.

	Total Length	Neck Length	Chamber Diameter	Max. Neck Diameter	Aperture Diameter
Pl. XVII, Fig. 3:	177	140	84	56	34
Pl. XVII, Fig. 4:	183	146	75	56	40

ILLUSTRATED SPECIMENS:

Pl. XVII, fig. 3; Sample SE/10-1/8750/2, Co-ordinate 121.0/38.0

Pl. XVII, fig. 4; Sample SE/10-1/8750/3, Co-ordinate 108.5/40.7

LOCALITY: Only two specimens of this species were observed from the SE/10-1 well at 8,750 feet depth.

REMARKS: The assignment of this species to the genus *Fungochitina* Taugourdeau, 1966, is very tentative, based largely on its short body and disproportionately long neck. *Fungochitina*, as diagnosed by Taugourdeau has a short conical body chamber with a long cylindrical neck. The discoid shaped body chamber and distinctly tapering neck of these specimens do not fully meet the diagnosis of the genus *Fungochitina*. However, only two specimens of this species were observed in the entire samples and are not adequate for full diagnosis. The discoid shape of the body chambers of the specimens might be due to deformation.

Genus HOEGISPHAERA Staplin, 1961

Type species: *Hoegisphaera glabra* Staplin 1961.

DIAGNOSIS: Body spherical. One hemisphere provided with a thickened circular ring, enclosing an operculum. The operculum is often found detached from the body. Colour dark amber-brown. Known species laevigate to wrinkled.

HOEGISPHAERA GLABRA Staplin, 1961

Plate XVIII, Figures 6, 7, 8

1961: *Hoegisphaera glabra* Staplin, Paleont. 4(3), p. 419, Pl. 50, figs. 5-7.

1965: *Hoegisphaera glabra* Staplin, Taugourdeau, Rev. Micropaléo., 8(2), p. 66, Pl. 1, figs. 19-22.

1967: Hoegisphaera glabra Staplin, Beju, Paleobot. Palynol. 5(1-4), Pl. II, figs. 17-18.

1971: Hoegisphaera cf. H. glabra Staplin, 1961, Legault, Unpubl. Ph.D. Thesis, p. 146, Pl. IX, figs. 1-8.

1972: Hoegisphaera glabra Staplin, Urban, Bull. Amer. Paleont., 63 (275), p. 22, Pl. 4, figs. 4-12.

DESCRIPTION: Test small, spherical; aperture circular with a thickened ring, operculum external; wall usually wrinkled, rough textured.

DIMENSIONS (in microns): 20 specimens measured.

	Test Diameter	Aperture Diameter	Operculum Diameter
Range:	49-64	22-35	28
Mean:	56	30	28

ILLUSTRATED SPECIMENS:

Pl. XVIII, fig. 6, Sample UC/19-2A/9010/2, Co-ordinate 121.6/57.5

Pl. XVIII, fig. 7, Sample UC/19-2A/9010/3, Co-ordinate 116.5/32.3

Pl. XVIII, fig. 8, Sample UC/19-2A/9010/1, Co-ordinate 113.4/49.4

LOCALITY: This species occurs commonly in all the three wells.

OCCURRENCE AND STRATIGRAPHIC RANGE: Staplin (1961, p. 419) first described this species from the Duvernay Formation (Upper Devonian) of Alberta, Canada. The species has been reported from various Devonian sediments, e.g: Lower Frasnian, Boulonnais, France (Taugourdeau, 1965); Lower Devonian of the Moesian Platform, Romania (Beju, 1967); Middle Devonian Hamilton Group, Canada Legault (1971, Unpubl. Ph.D. Thesis),

and Middle Devonian Cedar Valley Formation, Iowa (Urban, 1972). The known stratigraphic range of this species is Ordovician to Upper Devonian.

REMARKS: The Ghanaian specimens of this species are similar to other specimens recorded elsewhere.

Genus LAGENOCHITINA Eisenack, 1931

Type species: Lagenochitina baltica Eisenack, 1931

DIAGNOSIS: Test large; body chamber sub-spherical to oval; neck cylindrical; flexure distinct; shoulder inconspicuous; basal edge rounded.

LAGENOCHITINA AMOTTENSIS Grignani and Mantovani, 1964

Plate XIII, Figures 10, 11, 13

1964: Lagenochitina amottensis Grignani and Mantovani, Rev. Micropaléo. 4(4), p. 247, Pl. 2, figs. 18, 19.

1971: Lagenochitina cf. L. amottensis Grignani and Mantovani, 1964, Legault, 1971 (Unpubl. Ph.D. Thesis, Univ. Oklahoma), p. 162, Pl. XII, fig. 1.

DESCRIPTION: Test medium size, flask shaped; body chamber ovoid; neck cylindrical 1/3-2/5 total length of the test; wall smooth to somewhat rough textured; prosome not observed.

DIMENSIONS (in microns): 3 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	248-257	93-99	81-115	34-37	40-41
Mean:	250	97	93	36	41

ILLUSTRATED SPECIMENS:

Pl. XIII, fig. 10, Sample SE/10-1/8000/4, Co-ordinate 119.9/34.8

Pl. XIII, fig. 11, Sample A-1/1286-1288/5, Co-ordinate 117.0/36.8

Pl. XIII, fig. 13, Sample A-1/1404-1406/1, Co-ordinate 113.7/39.2

LOCALITY: This species is rare, one specimen was observed in the SE/10-1 well and a few others in the A-1 well. It was not found in the UC/19-2A well.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first described from the Middle and Upper Devonian sediments in Morocco by Grignani and Mantovani (1964). The species has also been observed from the Middle Devonian Hamilton Group, Canada (Legault, 1971, Unpubl. Th.D. Thesis).

REMARKS: The Ghanaian specimens of this species are generally similar to the Moroccan specimens.

LAGENOCHITINA sp. 1

Pl. XVIII, Figure 14

DESCRIPTION: Test medium size with sub-globular body chamber and a short cylindrical neck, length of neck about 1/3 total length of test; wall minutely verrucose; prosome indistinct.

DIMENSIONS: (in microns): One specimen measured.

Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
158	62	124	59	59

ILLUSTRATED SPECIMEN:

Sample UC/19-2A/7700/4, Co-ordinate 118.5/37.4

LOCALITY: Only the figured specimen of this species was found in the UC/19-2A well, at 7,700 feet depth.

LAGENOCHITINA sp. 2

Plate XVIII, Figure 9

DESCRIPTION: Test medium size, body chamber sub-conical merging into a short neck with a flaring lip; flexure broad, distinct; shoulder absent; basal edge rounded; base convex; wall thick, opaque, rough textured; prosome not observed.

DIMENSIONS (in microns): One specimen measured.

Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
164	78	124	44	53

ILLUSTRATED SPECIMEN:

Sample A-1/1224-1226/1, Co-ordinate 120.2/31.8

LOCALITY: This species is very rare; only the figured specimen was found in the A-1 well at about 4,046 feet deep of the well.

Genus RHABDOCHITINA Eisenack, 1931

Type species: Rhabdochitina magna Eisenack, 1931

DIAGNOSIS: Chitinozoa with large, cylindrical test.

RHABDOCHITINA sp. cf. R. MAGNA Eisenack, 1931

Plate XVIII, Figure 1

1967: Rhabdochitina magna Eisenack, Boekel, Atas do Simpósio sôbre a

Biota Amazônica 1 (Geosciências): 87-119, p. 107 Pl. II, fig. 23.

DESCRIPTION: Test elongate cylindrical; wall opaque, black; prosome not observed.

DIMENSIONS (in microns): One specimen measured.

Total Length	Maximum Diameter
403+	102

LOCALITY: This species is rare; only two specimens were observed from the SE/10-1 well at 8,600 feet depth.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species has been reported from Ordovician to Silurian sediments in Europe, but similar specimens have been recorded from Silurian to Lower Devonian sediments in Brazil (Boekel, 1967, p. 107).

RHABDOCHITINA sp. cf. R. CLAVIFORMIS Taugourdeau, 1961

Plate XVIII, Figure 3

1961: *Rhabdochitina claviformis* Taugourdeau, Rev. Micropaléo., 4(3), p. 150, Pl. 4, figs. 69-70.

1967: *Rhabdochitina claviformis* Taugourdeau, Boekel, Atas do Simpósio sôbre a Biota Amazônica 1 (Geociências): 87-119, p. 106, Pl. III, fig. 28.

DESCRIPTION: Test large, claviform; wall smooth.

DIMENSIONS (in microns): One specimen measured.

Total Length	Maximum Diameter
434+	130

ILLUSTRATED SPECIMEN:

Sample SE/10-1/9050/4, Co-ordinate 121.0/54.0

LOCALITY: This species is very rare, only the figured specimen was found from the SE/10-1 well at 9,050 feet depth.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first described from the Silurian of France by Taugourdeau (1961). It has also been observed from the Silurian of Brazil (Boekel, 1967).

REMARKS: The only specimen observed from Ghana is poorly preserved.

RHABDOCHITINA sp. 1

Plate XVIII, Figure 10

DESCRIPTION: Test larger, cylindrical with a rounded base and a short neck; an antler-shaped structure occurs at the oral end which probably represents a broken portion of another test; wall opaque, rough textured; prosome not observed.

DIMENSIONS (in microns): One specimen measured.

Total Length	Neck Length	Maximum Diameter	Neck Diameter
279	31	75	37

ILLUSTRATED SPECIMEN:

Sample UC/19-2A/9010/5, Co-ordinate 116.2/62.2

LOCALITY: Only the figured specimen was observed from the UC/19-2A well at 9,010 feet deep.

Genus SPHAEROCHITINA Eisenack, 1955

Type species: Lagenochitina sphaerocephala (Eisenack, 1932) Eisenack, 1955.

DIAGNOSIS: Chitinozoa with cone-, sphere-, or broadly mushroom-shaped body chambers and sub-cylindrical necks; wall smooth or with minute tubercles or small, thick, erect spinules.

SPHAEROCHITINA SPHAEROCEPHALA (Eisenack, 1932) Eisenack, 1955

Plate XV, Figures 9, 10

1932: Lagenochitina sphaerocephala Eisenack, Paläont. Zeit., 14 (271-272), Pl. 12, figs. 14, 15.

1955: Sphaerochitina sphaerocephala Eisenack, Senck. Leth., 36 (1-2), 162, Pl. 1, figs. 5, 6.

1960: Sphaerochitina sphaerocephala Eisenack, Taugourdeau and Jekhowsky, Rev. Inst. Pétrole, XV (9), p. 1232, Pl. III, fig. 43.

1962: Sphaerochitina sphaerocephala Eisenack, Beju and Danet, Petrol şi Gaze, 13 (12), p. 534, Pl. II, figs. 21.

1964: Sphaerochitina sphaerocephala (Eisenack), Grignani and Mantovani, Rev. Micropaléo. 6(4), p. 254, Pl. 4, figs. 15, 16.

1964: Sphaerochitina sphaerocephala (Eisenack), Cramer, Leidse Geol. Med., 30, p. 353, Pl. XX, figs. 4-6.

1968: Sphaerochitina sphaerocephala (Eisenack), Jardiné and Yapaudjan,

Rev. Inst. Fr. Pétrole XXIII (4), Pl. 5, fig. 15.

1961: Sphaerochitina sphaerocephala Eisenack, Costa An. Acad. Brasil. Ciênc., 43, p. 263, fig. 88.

DESCRIPTION: Test flask shaped; body chamber sub-globular; neck long, cylindrical, slightly flared at the lip, length of neck about 1/2 the total length of the test; wall scaley on neck and minute spines 3.2-5.3 microns long and 1.5-2.0 microns maximum diameter on body chamber; prosome short, annulated, within the neck, or absent in some specimens.

DIMENSIONS (in microns): 4 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	233-248	124-140	93-96	42-44	56-59
Mean:	241	132	95	43	57

ILLUSTRATED SPECIMENS:

Pl. XV, fig. 9, Sample SE/10-1/8250/2, Co-ordinate 112.2/37.4

Pl. XV, fig. 10, Sample SE/10-1/8220/4, Co-ordinate 119.4/35.4

LOCALITY: This species is rare; only a few specimens were found between 8,220-8,250 feet depth in the SE/10-1 well. It was not observed from the other two wells.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species occurs widespread. It was first described from Silurian glacial erratics in the Baltic region by Eisenack (1932), and has been reported from various Silurian and Devonian sediments as follows: Silurian, Moldoveneasca Platform, Romania (Beju and Danet, 1962); Upper Silurian to Lower Devonian,

NW Spain (Cramer, 1964); Silurian, France (Jardiné and Yapaudjian, 1968); Upper Devonian of the Sahara (Taugourdeau and Jekhowsky, 1960), Upper Devonian, Morocco (Grignani and Mantovani, 1964), and Lower Silurian, Brazil (Costa, 1971). The stratigraphic range of the species is Lower Silurian to Upper Devonian.

REMARKS: The Ghanaian specimens of this species are similar to other specimens recorded elsewhere.

SPHAEROCHITINA PILOSA Collinson and Scott, 1958

Plate XIV, Figures 11, 12, 18-21

1958: Sphaerochitina pilosa Collinson and Scott, Illinois State Geol. Surv. Circ. 247, p. 20, Pl. 3, figs. 1-5, text-fig. 10.

1959: Sphaerochitina pilosa Collinson and Scott, Dunn, Jour. Paleont. 33 (b), p. 1014, Pl. 127, figs. 9-13.

1960: Sphaerochitina cf. pilosa Collinson and Scott, Taugourdeau and Jekhowsky, Rev. Inst. Fr. Pétrole, XV (9), p. 1232, Pl. XI, figs. 153, 154, 155, Pl. XII, fig. H.

1964: Sphaerochitina cf. pilosa Collinson and Scott, Grignani and Mantovani, p. 254, Pl. 4, fig. 3.

1972: Sphaerochitina pilosa Collinson and Scott, Urban, Bull. Amer. Paleont., 63 (275), p. 25, Pl. 4, figs. 1-3.

DESCRIPTION: Test flask shaped; body chamber conical; neck cylindrical, about 1/3 total length of the test; basal edge rounded, base convex, wall ornamented with simple, minute spines 3.1-5.5 microns long and 1.8-2.4 microns maximum diameter, spines densely and uniformly distributed

all over the body; prosome, short, plug-like, within the neck.

DIMENSIONS (in microns): 20 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	130-161	47-65	87-90	31-34	31-36
Mean:	146	54	88	33	34

ILLUSTRATED SPECIMENS:

Pl. XV, fig. 11, Sample UC/19-2A/9013/3, Co-ordinate 124.3/56.2

Pl. XV, fig. 12, Sample A-1/1286-1288/3, Co-ordinate 116.7/34.6

Pl. XV, fig. 18, Sample UC/19-2A/9010/4, Co-ordinate 130.1/28.9

Pl. XV, fig. 19, Sample UC/19-2A/8290/5, Co-ordinate L110.7/32.6

Pl. XV, fig. 20, Sample A-1/1404-1406/1, Co-ordinate 117.1/40.0

Pl. XV, fig. 21, Sample UC/19-2A/9010/3, 120.8/21.2

LOCALITY: This species occurs commonly at various horizons in all the three wells studied.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first described from the Middle Devonian Cedar Valley Formation of Illinois by Collinson and Scott (1958). Dunn (1959) and Urban (1972) have recorded it from the same formation in Iowa. The species has also been observed from the Silurian-Middle Devonian in the Sahara (Taugourdeau and Jekhowsky (1960), and Middle to Upper Devonian of Morocco by Grignani and Mantovani (1964). The stratigraphic range of this species is Silurian to Upper Devonian.

REMARKS: The Ghanaian specimens of this species are similar to other specimens recorded elsewhere.

SPHAEROCHITINA SCHWALBI Collinson and Scott, 1959

Plate XIV, Figures 5, 6, 8, 9, 11, 12, 14, 15

1958: Sphaerochitina schwalbi Collinson and Scott, Illinois State Geol. Surv. Circ. 247, p. 23, Pl. 3, figs. 6-10, text-fig. 11.

1959: Sphaerochitina schwalbi Collinson and Scott, Dunn, Jour. Paleont. 33(6), p. 1015, Pl. 127, figs. 5-8.

DESCRIPTIONS: Test, short, conical shaped; body chamber conical with maximum diameter near the aboral end; neck very short, almost undifferentiated from lip, occasionally flared; basal edge rounded; base slightly convex; wall ornamented with close-set, very fine spines which occur all over the body chamber and the neck; prosome plug-like within the neck.

DIMENSIONS (in microns): 25 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	118-130	16-46	87-93	34-47	34-37
Mean:	124	31	104	43	43

ILLUSTRATED SPECIMENS:

Pl. XIV, fig. 5, Sample SE/10-1/8300/3, Co-ordinate 112.3/41.4

Pl. XIV, fig. 6, Sample SE/10-1/8300/4, Co-ordinate 121.4/27.1

Pl. XIV, fig. 8, Sample SE/10-1/8300/4, Co-ordinate 118.0/41.2

Pl. XIV, fig. 9, Sample SE/10-1/8220/3, Co-ordinate 111.7/35.3

Pl. XIV, fig. 11, Sample UC/19-2A/9010/3, Co-ordinate 124.3/56.2

Pl. XIV, fig. 12, Sample A-1/1286-1288/3, Co-ordinate 124.8/33.4

Pl. XIV, fig. 14, Sample UC/19-2A/8700/4, Co-ordinate 121.8/41.8

Pl. XIV, fig. 15, Sample UC/19-2A/8600/2, Co-ordinate 126.5/26.5

Pl. XIV, fig. 16, Sample UC/19-2A/8650/2, Co-ordinate 126.6/49.6

LOCALITY: This species occurs commonly in all the three wells studied. They are usually associated with S. pilosa.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first described from the Middle Devonian Cedar Valley Formation of Illinois by Collinson and Scott (1958). Dunn (1959) found the species from the same formation in Iowa.

REMARKS: Sphaerochitina schwalbi differs from S. pilosa by its shorter neck and broader conical body chamber. Intermediate forms, however, occur and the assignment of such varieties to one or the other species becomes very subjective.

Collinson and Scott (op. cit.) reported that the "collar" or lip of the Cedar Valley Formations are not ornamented by the short, simple spines which densely cover the neck and the body chamber. In the Ghanaian specimens the "collar" or lip is similarly ornamented by the short, simple spines on the body; besides, a few of the specimens possess flared lips which are, as well, ornamented.

SPHAEROCHITINA BREVISPINOSA Grignani and Mantovani, 1964

Plate XV, Figures 12

1964: Sphaerochitina brevispinosa Grignani and Mantovani, Rev. Micro-paléo., 6(4), p. 252, Pl. 4, figs. 5-6.

DESCRIPTION: Test, flask shaped with a sub-globular to ovoid body chamber

and a short, almost undefined neck, neck flared at the lip; wall ornamented with simple spines 9.3-15.5 microns long and 2.0-3.1 microns maximum diameter, spines sparsely and randomly distributed all over the body; some spines at the lip appear to emerge from the inside wall of the lip; prosome not observed.

DIMENSIONS (in microns): One specimen measured.

Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
177	46(?)	87	40	65

ILLUSTRATED SPECIMEN:

Sample SE/10-1/8000/4; Co-ordinate 116.6/30.4.

LOCALITY: This species was only observed from the SE/10-1 well.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was described by Grignani and Mantovani (1964) from the Middle and Upper Devonian of Morocco.

REMARKS: The Ghanaian specimens of this species are fairly similar to the Moroccan specimens by the shape of the test. The Ghanaian specimens however appear to have much longer spines than the Moroccan specimens.

SPHAEROCHITINA CUVILLIERI Taugourdeau, 1962

Plate XVI, Figures 2-4

1962: Sphaerochitina cuvillieri: Taugourdeau, Rev. Micropaléo., 4(4), p. 233, 1. 1, figs. 18, 19.

1964: Sphaerochitina cuvillieri: Taugourdeau, Grignani and Mantovani, Rev. Micropaléo., 6(4), p. 254, 1. 4, figs. 10, 11.

1971: Sphaerochitina cuvillieri: Taugourdeau, Costa, An. Acad. Brasil. Cienc., 43, p. 261, fig. 86.

DESCRIPTION: Test flask shaped; body sub-ovoid; neck sub-cylindrical, flared at the lip; wall ornamented with thin spines 9.3-10 microns long and 1.0-1.5 microns maximum diameter; spines in many specimens are abraded but the spine bases were quite evident; some few specimens have their spines interconnected at the base; prosome plug-like within the neck.

DIMENSIONS (in microns): 5 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Range:	171-186	60-62	87-99	40-53	40-68
Mean:	180	61	90	47	56

ILLUSTRATED SPECIMENS:

Pl. XVI, fig. 2, Sample SE/10-1/8000/3, Co-ordinate 115.8/43.1

Pl. XVI, fig. 3, Sample SE/10-1/8000/2, Co-ordinate 122.4/39.8

Pl. XVI, fig. 4, Sample A-1/1266-1268/3, Co-ordinate 125.5/28.2

LOCALITY: This species was found in the SE/10-1 well at 8,000 feet depth and a few specimens in the A-1 well. The species was not observed in the UC/19-2A well.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species has been described from the Upper Devonian in the Sahara (Taugourdeau, 1962). Grignani and Mantovani (1964) reported the species from the Upper Devonian in Morocco, and Coster (1971) has recorded it from the Lower and Middle Devonian in Brazil.

REMARKS: The Ghanaian specimens of this species are similar to other specimens which have been recorded elsewhere. A few specimens of the species found in Ghana have some of their spines interconnected. These varieties are quite different from *Angochitina mourai* (Lange, 1949) Lange 1967, some of this have similar characteristics in the spine arrangements. *Angochitina mourai* has spherical or globular body chamber as compared with the sub-ovoid body chamber of *Sphaerochitina cuvillieri*.

SPHAEROCHITINA sp. 1

Plate XIV, Figures 1-4

DESCRIPTION: Test flask shaped; body chamber sub-ovoid with the greatest diameter near the base; neck short, about 1/3-1/4 total length of the test, usually flaring at the lip; wall ornamented with simple and occasionally bifurcate spines 12-15 microns long and 2.5-3.0 microns maximum diameter, spine size reduced at the lip; some specimens have relatively larger spines near the base; prosome short, plug-like within the neck, or absent in some specimens.

DIMENSIONS (in microns): 10 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Pl. XIV, fig. 2:	186	62	93	40	47
Range:	124-186	31-62	68-93	37-47	37-47
Mean:	158	43	78	38	43

ILLUSTRATED SPECIMENS:

Pl. XIV, fig. 1, Sample SE/10-1/8250/3, Co-ordinate 121.6/37.0

Pl. XIV, fig. 2, Sample UC/19-2A/8600/2, Co-ordinate 126.0/37.4

Pl. XIV, fig. 3, Sample UC/19-2A/8600/2, Co-ordinate 126.2/52.0

Pl. XIV, fig. 4, Sample UC/19-2A/8800/4, Co-ordinate 118.5/52.0

LOCALITY: This species occurs commonly in all the three wells studied.

REMARKS: Most specimens of this species observed appeared to be folded at the base. The species is generally similar to *Sphaerochitina schwalbi* Collinson and Scott in the shape of the test. *S. schwalbi* however, has minute, simple spines as contrasted with simple and occasionally bifurcate much longer spines observed in *S.* sp. 1. A few specimens of this species have relatively larger spines resembling those of *Ancyrochitina* sp. cf. *A.* sp. Jansonius. However, *A.* sp. cf. *A.* sp. Jansonius has more densely distributed spines which are much finer. Distinct basal processes also occur in *A.* sp. cf. *A.* sp. Jansonius.

SPHAEROCHITINA sp. 2

Plate XIV, Figures 7, 10, 13, 17

DESCRIPTION: Test, short, cylindro-globoid; body chamber, sub-globular to conoid with maximum diameter near the base; neck short, cylindrical or occasionally flared at the lip; wall sparsely ornamented with simple spines, 10.0-12.5 microns long and 1.5-2.3 microns maximum diameter, prosome elongate and annulated or short and plug-like within the neck.

DIMENSIONS (in microns): 10 specimens measured:

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Pl. XIV, fig. 7:	177	62	96	37	40
Range:	140-177	47-62	96-105	34-105	37-47
Mean:	155	47	99	37	40

ILLUSTRATED SPECIMENS:

Pl. XIV, fig. 7, Sample UC/19-2A/8700/2, Co-ordinate 123.2/56.0

Pl. XIV, fig. 10, Sample UC/19-2A/8700/1, Co-ordinate 118.4/23.4

Pl. XIV, fig. 13, Sample UC/19-2A/8700/1, Co-ordinate 124.5/43.2

Pl. XIV, fig. 17, Sample UC/19-2A/8700/1, Co-ordinate 121.6/66.2

LOCALITY: This species occurs commonly in the UC/19-2A well at 8,700 feet depth. A few specimens were also observed from the SE/10-1 well.

REMARKS: This species differs from *Sphaerochitina schwalbi* Collinson and Scott by its well defined and longer neck and sparsely distributed spines. *Sphaerochitina* sp. 1 has much thicker and more densely distributed spines.

SPHAEROCHITINA sp. 3

Plate II, Figures 5, 6

Plate XV, Figures 1, 5-8, 11, 13-15.

DESCRIPTION: Test, flask shaped with an ovoid body chamber and a long, slightly tapering neck about 3/5 the total length of the neck; neck flared at the lip; wall ornamented with finely hispid to fairly long and thin spines 2-10 microns long and less than 1.5 microns maximum diameter, spines distributed uniformly over entire body; prosome long, annulated within the neck.

DIMENSIONS (in microns): 10 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Pl. XV, fig. 8:	220	93	90	40	43
Range:	217-254	100-127	87-96	38-47	43-68
Mean:	240	107	93	43	60

ILLUSTRATED SPECIMENS:

Pl. II, figs. 5, 6, Sample SE/10-1/8250

Pl. XV, fig. 1, Sample UC/19-2A/8650/1, Co-ordinate 121.3/56.2

Pl. XV, fig. 5, 6, Sample SE/10-1/8250/5, Co-ordinate 119.0/37.1

Pl. XV, fig. 7, Sample SE/10-1/8250/4, Co-ordinate 126.4/42.2

Pl. XV, fig. 8, Sample SE/10-1/8220/1, Co-ordinate 115.9/43.8

Pl. XV, fig. 11, Sample A-1/1454-1456/1, Co-ordinate 120.5/33.2

Pl. XV, fig. 13, Sample SE/10-1/8750/2, Co-ordinate 113.5/30.4

Pl. XV, fig. 14, Sample A-1/1454-1456/1, Co-ordinate 114.8/43.5

Pl. XV, fig. 15, Sample A-1/1454-1456/2, Co-ordinate 123.1/35.4

LOCALITY: This species occurs commonly in the SE/10-1 well. A few specimens of the species were found in the A-1 well, and only one specimen of the species was observed from the UC/19-2A well.

REMARKS: This species has similarity in the shape of the test to *Sphaerochitina lucianoi* Sommer and Van Boekel (1965, Pl. II; Pl. III, figs. 3-6; text-fig. 3), but a "body chamber slit" and a "ring-shaped peripheral swelling" described for *S. lucianoi* were not observed in *S.* sp. 3. *Sphaerochitina fenestrata* described by Taugourdeau and Jekhowsky (1960) from the Famennian of the Sahara has much longer neck and somewhat globu-

lar body chamber. S. vitrea Taugourdeau has somewhat conical body chamber with a broad cylindrical neck.

UROCHITINA Taugourdeau and Jekhowsky, 1960

Type species: Urochitina simplex Taugourdeau and Jekhowsky, 1960.

DIAGNOSIS: Tests medium to small size, elongate, pyriform to claviform; neck long; base rounded; at aboral pole a long, narrow copula or sleeve occurs; prosome elongate, with annulated tube.

UROCHITINA sp. cf. U. BASTOSI van Boekel, 1967

Plate XVIII, Figure 5

1967: Urochitina bastosi van Boekel, Div. Geol. Min. Dept. Nac. Prod. Min., Rio de Janeiro, G.B., p. 247, Pl. I, figs. 1-7, test--figs. 1, 1a, 1b.

1968: Urochitina bastosi van Boekel, van Boekel, Dept. Nac. Produc. Mineral, Div. Geol. Min., 146, p. 7, Pl. I, figs. 1-3.

1971: Urochitina bastosi van Boekel, Costa, An. Acad. Brasil. Ciênc., 43, p. 265 (fig. 92).

DESCRIPTION: Test medium size, body chamber elliptical; neck short, flaring; lip fringed or serrated at the periphery; flexure broad; base convex extending into a (broken?) appendix; wall thick, opaque; prosome not observed.

DIMENSIONS (in microns): One specimen measured.

Total Length	Neck Length	Max. Chamber Diameter	Neck Diameter	Aperture Diameter
261	78	78	44	59

ILLUSTRATED SPECIMEN: Sample SE/10-1/8250/1, Co-ordinate 119.0/31.8

LOCALITY: This species is very rare, only the figured specimen was found from the SE/10-1 well at 8,250 feet depth.

OCCURRENCE AND STRATIGRAPHIC RANGE: *Urochitina bastosi* was described by van Boekel (1967) from the Middle Devonian of Brazil. The species appears restricted to the Middle Devonian.

REMARKS: *Urochitina bastosi* as described by van Boekel has a long flaring neck and an elliptical body chamber the base of which is extended into a long filiform appendix which ends in a knob-like triangular loop. In the Ghanaian specimen, this filiform appendix appears to have broken off but its base to the body is quite evident. The Ghanaian specimen has much shorter neck as compared to the Brazilian specimens. *Urochitina simplex* Taugourdeau and Jekhowsky, though comparable in shape to the Ghanaian specimen is ornamented with long hair-like processes at the neck. *Urochitina verrucosa* Taugourdeau and Jekhowsky has the surface covered with verrucae and tufts of fine hair at the base, instead of the basal appendix.

CHITINOZOAN TYPE A

Plate XVI, figures 5, 8, 10

DESCRIPTION: Test flask shaped; body chamber ovoid; neck short, cylindrical, about 1/4-1/3 total length of the test; wall ornamented with densely distributed mesh-work of fine strands of about 1.5 microns diameter; prosome plug-like within the neck.

<u>DIMENSIONS</u> (in microns): 6 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Pl. XVI, fig. 8:	195	47	90	37	37
Range:	195-248	47-67	90-96	37-40	37-40
Mean:	238	60	93	39	39

<u>ILLUSTRATED SPECIMENS</u>:

Pl. XVI, fig. 5, Sample SE/10-1/8220/4, Co-ordinate 120.0/40.0

Pl. XVI, fig. 8, Sample UC/19-2A/8150/3, Co-ordinate 116.6/54.4

Pl. XVI, fig. 10, Sample SE/10-1/8220/3, Co-ordinate 118.5/64.3

<u>LOCALITY</u>: This species is rare; one specimen was found from the UC/19-2A well and a few specimens from the SE/10-1 well. The species was not observed from the A-1 well.

<u>REMARKS</u>: The general shape of the test of Chitinozoan type A is characteristic of the genus <u>Sphaerochitina</u> Eisenack, 1955. However, the wall of <u>Sphaerochitina</u> is either smooth or ornamented with simple or occasionally bifurcate spines.

CHITINOZOAN TYPE B

Plate I, Figures 5-7

Plate XVI, Figures 1, 12-13, 17

<u>DESCRIPTION</u>: Test medium size, flask shaped with a sub-globular body chamber and a short, sub-cylindrical neck about 1/3 the total length of the test; wall ornamented with closely-set, dense, meshwork of strands

or processes, which cover the entire surface of the test; diameter of these strands is less than one micron; when poorly preserved, the strands form a sort of net on the surface of the body; prosome not observed.

DIMENSIONS (in microns): 5 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Pl. XVI, fig. 13:	217	78	109	63	74
Range:	217-254	78-93	109-115	63-68	71-74
Mean:	240	85	112	65	73

ILLUSTRATED SPECIMENS:

Pl. I, figs. 5-7, Sample SE/10-1/8200

Pl. XVI, fig. 1, Sample SE/10-1/8220/2, Co-ordinate 120.8/41.0

Pl. XVI, figs. 12, 13, Sample SE/10-1/8220/4, Co-ordinate 125.9/39.7

Pl. XVI, fig. 17, Sample SE/10-1/8220/3, Co-ordinate 116.3/44.1

LOCALITY: This species was found only from the SE/10-1 well at 8,220 feet depth. It was not observed from the other two wells.

REMARKS: The shape of Chitinozoan type B is characteristic of the genus *Angochitina* Eisenack, 1931. *Angochitina* however, has spinose ornamentation. *Stephanochitina* Grignani and Mantovani, 1964, has similar test shape as Chitinozoan type B but the ornamentation of *Stephanochitina* consists of several coarse branching spines, the tips of which in part are anastomose. The ornamentation observed in Chitinozoan type B is closely similar to Chitinozoa type A but they differ in the shape of the tests.

CHITINOZOAN TYPE C

Plate XVI, Figures 6, 7

DESCRIPTION: Test medium size, sub-cylindrical with almost straight to broadly concave sides, chamber/neck junction indistinct; base rounded, convex; wall ornamented with densely distributed fine mesh-work of strands similar to the ornamentation observed in Chitinozoan types A and B; prosome not observed.

DIMENSIONS (in microns): Two specimens measured.

	Total Length	Maximum Diameter	Aperture Diameter
Pl. XVI, fig. 6:	202	90	74
Pl. XVI, fig. 6:	190	84	62

ILLUSTRATED SPECIMENS:

Pl. XVI, fig. 6, Sample A-1/1522-1524/2, Co-ordinate 125.6/34.4

Pl. XVI, fig. 7, Sample SE/10-1/8700/1, Co-ordinate 118.0/28.4

LOCALITY: Only the two figured specimens of this species were observed, one from the SE/10-1 well at 8,700 feet depth and the other from the A-1 well at about 5,030 feet.

CHITINOZOAN TYPE D

Plate XVI, Figures 15, 16

Text--Figure 19d

DESCRIPTION: Test medium size, bulb-shaped; body chamber sub-globular,

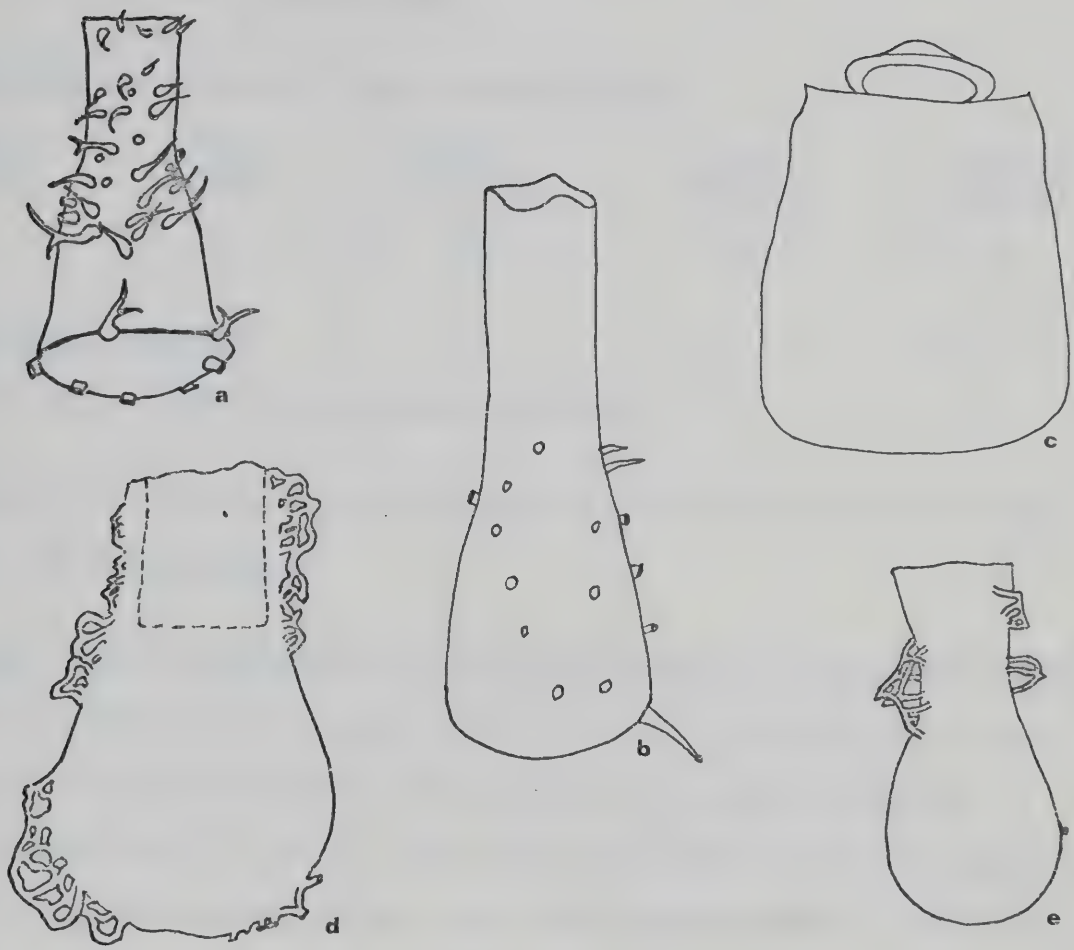

Figure 19. Morphological Variability of some Chitinozoa species from the Devonian of Ghana. (Semi-diagrammatic. Magnification of all illustrated specimens X300, unless otherwise stated). 19a, *?Alpenachitina* sp. 1; 19b, *?Conochitina* sp. 5; 19c, *Eisenachitina* sp. 1; 19d, Chitinozoa type D (X480); 19e, Chitinozoa type E.

neck short, sub-cylindrical; flexure broad; wall densely covered with mesh-work of interwoven strands of 1.8-3.2 microns diameter; prosome appears plug-like within the neck.

DIMENSIONS (in microns): One specimen measured.

Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
143	47	56	47	47

ILLUSTRATED SPECIMEN:

Sample SE/10-1/9050/6, Co-ordinate 124/0/30.0

LOCALITY: A few specimens of this species were observed from the SE/10-1 well at 9,050 feet depth.

REMARKS: The few specimens of this species observed in the samples were too poorly preserved to make complete diagnosis of the ornamentation pattern possible. The ornamentation of this species is closely similar to Chitinozoan types A, B and C, except that the strands forming the mesh-work of this species are broader than that of Chitinozoan types A, B and C.

CHITINOZOAN TYPE E

Plate II, Figures 3, 4

Plate XV, Figures 2, 3, 4

Text--figure 19e

DESCRIPTION: Test medium size, flask shaped; body chamber sub-globular; neck cylindrical, slightly flared at the lip, length of neck 1/2-1/3 total length of the test; wall ornamented with a network of thin strands

of about 2.8-3.0 microns in diameter; this network of strands becomes easily eroded from body surface but patches of it occur in various places; when the ornamentation is completely abraded, the wall appears very smooth; prosome elongate, plug-like within the neck.

DIMENSIONS (in microns): 4 specimens measured.

	Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
Pl. XV, fig. 4:	167	71	81	43	56
Range:	167-273	71-140	81-90	40-47	47-68
Mean:	240	110	87	43	46

ILLUSTRATED SPECIMENS:

Pl. II, figs. 3, 4, Sample A-1/1266-1268

Pl. XIV, fig. 2, Sample A-1/1266-1268/2, Co-ordinate 125.0/38.3

Pl. XIV, fig. 3, Sample A-1/1266-1268/1, Co-ordinate 116.0/37.8

Pl. XIV, fig. 4, Sample A-1/1298-1300/1, Co-ordinate 125.0/38.5

LOCALITY: This species was found only from the Atiavi-1 well. It was not observed from the two other wells.

REMARKS: This species differs from Chitinozoan type D by its longer neck and better defined network of thin strands.

CHITINOZOAN TYPE F

Plate XVIII, Figure 2

DESCRIPTION: Test elongate with a short, sub-rounded chamber and a long, broad and flaring neck, length of neck about 3/4 the total length of the

test; flexure broad, distinct; shoulder distinct, basal edge rounded with about eight short, broad, simple basal processes with blunt extremities, length of basal processes 10-15 microns long and 4-8 microns diameter at the base; wall opaque, with occasional spine bases; long, cylindrical blunt spines occur near the aperture, some of which appear to emerge from inside the wall of the lip; prosome not observed.

DIMENSIONS (in microns): One specimen measured.

Total Length	Neck Length	Chamber Diameter	Neck Diameter	Aperture Diameter
177	125	93	64	100

ILLUSTRATED SPECIMEN:

Sample SE/10-1/9050/4, Co-ordinate L110.7/8.0

LOCALITY: This species is very rare; only the figured specimen was observed from the SE/10-1 well at 9,050 feet depth.

Incertae Sedis

Group ACRITARCHA Evitt, 1963

Subgroup ACANTHOMORPHITAE Downie, Evitt and Sarjeant, 1963

Genus AMMONIDIUM Lister, 1970

Type Species: Baltisphaeridium microcladum Downie, 1963

DIAGNOSIS: Vesicle hollow, spherical to ellipsoidal, single-walled; vesicle wall smooth or sculptured; processes numerous, evenly spaced, more or less rigid, hollow, tapering, communicating freely with the vesicle cavity; distally the processes have equifurcate terminations; excystment by cryptosuture, apical or near-equatorial.

AMMONIDIUM sp. 1

Plate XIX, Figure 1

DESCRIPTION: Vesicle circular, small, 26-30 microns in diameter; processes numerous, short 3.8-4.0 microns long and 1.8-2.0 microns basal diameter, slightly tapering to the base of multifurcate tips.

DIMENSIONS (in microns): 30 specimens measured.

	Vesicle Diameter	Process Length	Process Basal Diameter
Pl. XIX, Fig. 1:	26	4.0	2.0
Range:	26-30	3.8-4.0	1.8-2.0
Mean:	28	4.0	1.9

ILLUSTRATED SPECIMEN:

Sample UC/19-2A/8480/1, Co-ordinate 112.6/35.5

LOCALITY: This species occurs commonly in all the three wells studied.

AMMONIDIUM sp. 2

Plate XIX, Figure 2

Plate XX, Figures 1-3

DESCRIPTION: Vesicle circular, 31-45 microns diameter with numerous, usually 24-36, equally spaced processes crossing the outline of the vesicle, processes hollow, gradually tapering to the base of equifurcate tips, process length 12-33 microns, process basal diameter 2.1-4.5 microns; tips 4-6 branches observed measuring 4.5-6.0 microns long; wall of vesicle and processes smooth or finely granular.

DIMENSIONS (in microns): 20 specimens measured.

	Vesicle Diameter	Process Length	Process Basal Diameter
Pl. XIX, Fig. 2:	37	15	3.5
Range:	31-45	10-34	2.1-4.5
Mean:	37	18	3.5

ILLUSTRATED SPECIMENS:

Pl. XIX, Fig. 2, Sample UC/19-2A/8480/1, Co-ordinate 117.2/36.5

Pl. XX, Fig. 1, Sample A-1/14 C/2, Co-ordinate 122.2/35.2

Pl. XX, Fig. 2, Sample UC/19-2A/7700/2, Co-ordinate 119.5/48.9

Pl. XX, Fig. 3, Sample SE/10-1/8450/3, Co-ordinate 109.0/51.5

LOCALITY: This species occurs commonly in all the three wells studied.

REMARKS: This species appears to be similar to *Ammonidium* (*Multiplicisphaeridium*?) *sprucegrovensis* described by Staplin (1961) from the Upper Devonian in central Alberta, Canada. The Canadian specimens have tetrafurcate tips and the tests are smooth, besides the length of the processes ranges from 10-16 microns. The Ghanaian specimens have longer processes, 10-34 microns; the tips are tetrafurcate, quinquefurcate or hexafurcate and the walls of many specimens observed are granular. *Ammonidium* sp. 1 is much smaller in size and has numerous short processes whose tips are invariably multifurcate.

AMMONIDIUM sp. 3

Plate XX, Figure 5

REMARKS: This is a very rare species, only the figured specimen was observed. It is similar to *Ammonidium* sp. 2 but has only six observed processes terminated by multifurcate tips. Vesicle diameter 47 microns; process length 30 microns. The figured specimen was found from the UC/19-2A well at 8,480 feet deep.

Genus CRAMERIA Lister, 1970

Type species: *Baltisphaeridium*? *duplex* Cramer, 1964

DIAGNOSIS: Double-walled acritarchs consisting of a hollow, thick single-walled central capsule of rounded polygonal form; surrounding the central capsule is a loosely attached thin, outer wall which extends to form three or more processes. Excystment by cryptosuture.

CRAMERIA PHAROANIS PHAROANIS (Deunff, 1954) Jardiné et al., 1972

Plate XXV, Figure 7

1954: Polyedryxium pharoanis Deunff, Comtes Rendus, Acad. Sci., Paris, 239, p. 1065, fig. 13.

1955: Polyedryxium pharoanis Deunff, Deunff, Bull. Microsc. Appl., (2)5, p. 143, text-fig. 13.

1972: Crameria pharoanis pharoanis (Deunff) Jardiné et al. Compte Rendu, 1, p. 301, Pl. 2, fig. 7

DESCRIPTION: Vesicle polyhedral or cubic shaped; wall double, an inner wall surrounded by an outer wall which is extended to form simple, spine-like processes at the corner of the vesicle; process tips sharply pointed; surface of vesicle smooth, surface of processes granular to echinate.

DIMENSIONS (in microns): 10 specimens measured.

	Vesicle Diameter	Process Length	Process Basal Diameter
Range:	28-36	24-28	3.1-3.4
Mean:	33	26	3.2

ILLUSTRATED SPECIMEN:

Sample SE/10-1/8450/3, Co-ordinate 115.6/33.5

LOCALITY: This species was observed from the three wells, but is rare.

OCCURRENCE AND STRATIGRAPHIC RANGE: Crameria pharoanis (Deunff) and its various sub-species have been recorded from various Devonian sediments; e.g.: Hamilton Group, Canada (Deunff, 1955); Frasnian in Belgium (Stockmans and Willière, 1962); Emsian to Frasnian in the Sahara (Jardiné et al., 1972). The stratigraphic range of Crameria pharoanis pharoanis (Deunff) Jardiné et al. of which the Ghanaian specimens are closely simi-

lar is Emsian or base Eifelian to Frasnian in the Sahara (Jardiné *et al*., op. cit.).

Genus EVITTIA Brito, 1967, emend. Lister, 1970

Type species: *Evittia sommeri* Brito, 1967

EMENDED DIAGNOSIS: Vesicle hollow, sub-spherical to polygonal, single-walled; vesicle wall may be smooth or sculptured; processes are heteromorphic, hollow, invariably granular to echinate, communicating freely with the vesicle cavity. Excystment by cryptosuture, apical or near equatorial.

EVITTIA GRANULATISPINOSUM (Downie, 1963) Lister, 1970

Plate XIX, Figure 6

1963: *Baltisphaeridium granulatispinosum* Downie, Palaeont., 6(4), p. 640, Pl. 91, figs. 1, 7; text-fig. 3c.

1967: *Baltisphaeridium granulatispinosum* Downie, Martin, Bull. Soc. Belge Géol. Paléont. Hydrol., 75 (3), p. 310, 326, Pl. 1, fig. 24.

1967: *Baltisphaeridium granulatispinosum* Downie, Lister and Downie, Palaeont., 10(2), Pl. 23, fig. 12.

1970: *Evittia granulatispinosum* (Downie) Lister, Palaeont. Soc. Mono., p. 67, Pl. 4, figs. 2, 3, 5-9, 12; Pl. 5, fig. 2; text-figs. 170, 20b.

1972: *Evittia granulatispinosa* (Downie) Lister, Deunff and Paris, Soc. Geol. Min. Bretagne, Bull. série C, 111(2), Pl. 1, fig. 6.

DESCRIPTION: Vesicle spherical to ellipsoidal, occasionally polygonal; processes few, spine-like, occasionally branched at the tip; wall coarsely granular to echinate.

DIMENSIONS (in microns): 10 specimens measured.

	Vesicle Diameter	Process Length	Process Basal Diameter
Range:	25-30	45-50	3.8-4.5
Mean:	27	48	4.3

ILLUSTRATED SPECIMEN:

Sample UC/19-2A/8480/2, Co-ordinate 119.3/29.6

LOCALITY: This species was observed from the UC/19-2A well, but is rare.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first described from the Wenlock, Shropshire (Downie, 1963). It occurs commonly in the Wenlock and Ludlow Series, Shropshire (Lister, 1970). The species has also been recorded from the Wenlock, Belgium (Martin, 1967) and Siluro-Devonian in the Plourach Region, North Coast (Deunff and Paris, 1972).

REMARKS: The Ghanaian specimens are closely similar to specimens recorded elsewhere.

EVITTIA REMOTA (Deunff, 1955) Lister, 1970

Plate XXII, Figures 1, 2, 4, 5

Plate XXIII, Figure 3

1955: *Veryhachium remotum* Deunff, Bull. Micros. Appl., 2(5), p. 146, Pl. 4, fig. 8.

1964: Veryhachium rabiosum Cramer, Leidse Geol. Med., 30, p. 299, Pl. V, fig. 7, Pl. VI, figs. 3, 8, Pl. VII, fig. 9, not figs. 5, 8.

1966 Veryhachium remotum Deunff, Rennes, p. 60, Pl. 4, fig. 28.

1967: Veryhachium sp. 1 and sp. 2, Beju, Paleobot. Palynol., 5(1-4), p. 45, Pl. II, figs. 1-4.

1968: Veryhachium sp. 2 (group V. remotum); Jardiné and Yapaudjian, Rev. Inst. Fr. Pétrole, 13(4), p. 464, Pl. 4, figs. 1, 2.

1970: Evittia remota (Deunff) Lister Palaeont. Soc. Mono., p. 69, Pl. 4, figs. 10-11, 13-15, Pl. 5, fig. 1.

1972: Evittia remota remota (Deunff) Jardiné et al. Compte Rendu, 1, p. 197, Pl. 1, figs. 11, 12.

DESCRIPTION: Vesicle variably shaped, usually tetrahedral, formed by fusion of broad bases of the processes; processes bifurcate; surface granular to echinate.

DIMENSIONS (in microns): 20 specimens measured.

	Total Diameter
Range:	87-188
Mean:	150

ILLUSTRATED SPECIMENS:

Pl. XXII, Fig. 1, Sample UC/19-2A/8480/4, Co-ordinate 122.3/73.2

Pl. XXII, Fig. 2, Sample UC/19-2A/8480/1, Co-ordinate 118.8/69.2

Pl. XXII, Fig. 4, Sample UC/19-2A/8950/1, Co-ordinate 119.7/25.4

Pl. XXII, Fig. 5, Sample UC/19-2A/8480/1, Co-ordinate 118.8/69.2

Pl. XXIII, Fig. 3, Sample UC/19-2A/8480/4, Co-ordinate 118.0/62.2

LOCALITY: This species occurs commonly in all the three wells studied.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species occurs very commonly in various Paleozoic sediments. The species has been recorded from the Devonian, Canada (Deunff, 1955, 1966); Devonian, Tunisia (Deunff, 1966); Middle Siegenian to Emsian, NW Spain (Cramer, 1964); Early to Middle Devonian, Brazil (Brito, 1964, in Lister, 1970, p. 70); Lower Devonian, Romania (Beju, 1967); Emsian to Givetian, Algeria (Jardiné and Yapaudjian (1968); Wenlock and Ludlow Series, Shropshire (Lister, op. cit.), and Emsian, Sahara, Algeria (Jardiné et al., 1972).

REMARKS: The Ghanaian specimens of this species are essentially similar to other specimens recorded elsewhere. The ornamentation of all the specimens observed varied from finely granular to coarsely granular or echinate.

EVITTIA sp. 1

Plate XXIII, Figure 2

DESCRIPTION: Vesicle made up of inflated bulbous bases of four processes symmetrically situated at right angles to each other; processes are bifurcated at the tips; wall coarsely granular to echinate.

DIMENSIONS (in microns): 10 specimens measured.

	Total Diameter
Pl. XXIII, fig. 2:	192
Range:	150-195
Mean:	160

ILLUSTRATED SPECIMEN:

Sample UC/19-2A/8950/3, Co-ordinate 115.5/64.8

LOCALITY: This species occurs in all the three wells studied but rare.

REMARKS: This species differs from *Evittia remota* (Deunff) Lister, by its bulbous basal processes and the absence of defined tetrahedral shape of the vesicle.

?EVITTIA sp. 2

Plate XX, Figure 9

REMARKS: This species is essentially similar to *Multiplicisphaeridium arbusculiferum* (Downie, 1963) Staplin *et al.*, 1965, by its sub-spherical vesicle and the nature of the bifurcating appendages, but it is ornamented with granulations.

DIMENSION (in microns): Figured specimen measured.

Total Diameter	Vesicle Diameter	Process Length	Process Basal Diameter
80	28	26	3.1-4.0

ILLUSTRATED SPECIMEN:

Sample UC/19-2A/8480/4, Co-ordinate 109.0/45.6

LOCALITY: This species was observed from the UC/19-2A well at 8,480 feet depth. It is rare.

Genus MICRHYSTRIDIUM (Deflandre, 1937) emend. Lister, 1970

Type species: Hystrichosphaera inconspicum Deflandre, 1935

EMENDED DIAGNOSIS: Vesicle sub-spherical to polygonal; processes are closed at the tips, generally homomorphic, simple, capitate or with very brief branches; vesicle small, mean and modal diameter of vesicles generally less than 20 microns; processes communicate freely with vesicle cavity; an inner wall, if present, is highly appressed to the outer wall; excystment by cryptosuture, dehiscence gradual by stages; position of suture apical or near-equatorial.

MICRHYSTRIDIUM STELLATUM Deflandre, 1945

Plate XIX, Figures 10, 11, 15, 16

1945: Micrhystridium stellatum Deflandre, Annls Paléont., 31, p. 65, Pl. 3, figs. 16-19.

1964: Micrhystridium stellatum (Deflandre) form group Cramer, Leidse Geol. Med., 30, p. 304, Pl. 9, figs. 8-13, Pl. 10, figs. 1-16, text-fig. 25.

1970: Micrhystridium stellatum Deflandre, Lister, Palaeont. Soc. Mono., p. 80, Pl. 9, figs. 1-17, Pl. 10, fig. 10, text-fig. 18j, 1-0.

DESCRIPTION: Vesicle small, variable in shape, sub-spherical, polygonal, or sub-polygonal with simple spine-like processes which are variable in form and length; wall smooth or occasionally finely granular.

DIMENSIONS (in microns): 20 specimens measured.

	Vesicle Diameter	Processes Length
Range:	10-20	12-35
Mean:	15	24

ILLUSTRATED SPECIMENS:

Pl. XIX, fig. 10, Sample UC/19-2A/8480/1, Co-ordinate 122.9/44.9

Pl. XIX, fig. 11, Sample UC/19-2A/8480/1, Co-ordinate 124.8/35.8

Pl. XIX, fig. 15, Sample UC/19-2A/8480/1, Co-ordinate 117.3/18.4

Pl. XIX, fig. 16, Sample UC/19-2A/8480/2, Co-ordinate 121.4/37.2

LOCALITY: This species occurs commonly in all the three wells.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species has been recorded from various Paleozoic sediments in various parts of the world. The known stratigraphic range is Llandovery to Lower Trias (Lister, 1970, p. 82).

Genus MULTIPLICISPHAERIDIUM Staplin, 1961, emend., Lister, 1970

Type Species: Multiplicisphaeridium ramispinosum Staplin, 1961

EMENDED DIAGNOSIS: Vesicle hollow, spherical to ellipsoidal, single-walled; processes with closed tips, heteromorphic, simple or compound branching; wall smooth or with minor ornamentation; no differentiation between vesicle wall and processes; process cavity in open connection with vesicle interior; excystment by cryptosuture, apical or near-equatorial.

MULTIPLICISPHAERIDIUM RAMUSCULOSUM (Deflandre, 1945) Lister, 1970

Plate XIX, Figures 3, 4, 9

Plate XX, Figure 6

1945: Hystrichosphaeridium ramusculosum Deflandre, Annls Paléont.,

31, p. 63, Pl. 1, figs. 8-16, text-figs. 38, 39.

1959: Baltisphaeridium ramusculosum (Deflandre) Downie, Palaeont., 2(1), p. 59, Pl. II, fig. 13

1963: Baltisphaeridium ramusculosum (Deflandre) Downie, Palaeont., 6(4), pp. 642-643, (no fig.).

1964: Baltisphaeridium ramusculosum (Deflandre) Cramer, Leidse Geol. Med., 30, p. 301, Pl. III, figs. 3(4), 4-6, 8, 9, text-fig. 22:4.

1966: Baltisphaeridium ramusculosum (Deflandre), Deunff, Rennes, p. 93, Pl. 5, figs. 57-60, 63.

1967: Baltisphaeridium ramusculosum (Deflandre), Beju, Rev. Palaeobot. Palynol., 5(1-4), p. 42 (no. fig.).

1968: Baltisphaeridium cf. ramusculosum (Deflandre) Jardiné and Yapaud-jian, Rev. Inst. Fr. Pétrole, 13(4), Pl. 3, figs. 8, 9.

1970: Multiplicisphaeridium ramusculosum (Deflandre) Cramer, Palaeont. Soc. Mono., p. 92, Pl. II, figs. 8, 11-14, Text-fig. 25a.

DESCRIPTION: Vesicle spherical to sub-spherical, processes about ten more or less, short, branching, closed at the tips; wall smooth or occasionally finely granular.

DIMENSIONS (in microns): 20 specimens measured.

	Vesicle Diameter	Processes Length	Process Diameter at Base
Range:	20-24	16-20	3.2-4.0
Mean:	22	18	3.5

ILLUSTRATED SPECIMENS:

Pl. XIX, fig. 3, Sample UC/19-2A/8480/3, Co-ordinate 125.3/55.6

Pl. XIX, fig. 4, Sample UC/19-2A/8480/2, Co-ordinate 118.8/22.8

Pl. XIX, fig. 9, Sample UC/19-2A/8480/3, Co-ordinate 121.5/44.6

Pl. XX, fig. 6, Sample A-1/14C/1, Co-ordinate 118.3/34.5

LOCALITY: This species occurs commonly in all the three wells studied.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species has been recorded from various Paleozoic sediments, such as Wenlock Shale, Shropshire Downie (1963); La Vid Shale (Devonian), NW Spain (Cramer, 1964); Calcaire d'Angers (Emsian), Anjou (Moreau-Benoit, 1967); Moesian Platform (Lower Devonian), Romania (Beju, 1967); and Wenlock and Ludlow Series, Shropshire (Lister, 1970).

REMARKS: The Ghanaian specimens of this species are essentially similar to various recorded specimens. Some specimens, however, bear general resemblance to Multiplicisphaeridium? ramispinosum Staplin, described from the Frasnian in central Alberta (Staplin, 1961).

MULTIPLICISPHAERIDIUM ARBUSCULIFERUM (Downie, 1963) Staplin, Jansonius and Pocock, 1965

Plate XIX, Fig. 5, 8, 7

1963: Baltisphaeridium arbusculiferum Downie, Palaeont., 6(4), p. 644, Pl. 91, fig. 5, text-fig. 3d.

1964: Baltisphaeridium arbusculiferum Downie, Cramer, Leidse Geol. Med., 30, p. 289, Pl. II, figs. 17, 18; Pl. III, figs. 1, 2, 10, 11; text-figs. 16:1-6.

1965: Multiplicisphaeridium arbusculiferum (Downie) Staplin, Jansonius

and Pocock, Neues Jb. Miner. Geol. Palaont. Abh., 123(2), p. 181, (no fig.).

1967: Baltisphaeridium arbusculiferum Downie, Moreau-Benoit, Rev. Micropaléo., 10(3), p. 201, Pl. 1, fig. 12.

1967: Baltisphaeridium arbusculiferum Downie Beju, Rev. Palaeont. Palynol., 5(1-4), p. 42, (no fig.).

1970: Multiplicisphaeridium arbusculiferum (Downie) Staplin, Jansonius and Pocock, Lister, Palaeont. Soc. Mono., p. 86, Pl. 10, figs. 14-17, 19; Pl. II, figs. 1-2; text-fig. 25c.

DESCRIPTION: Vesicle, spherical, sub-spherical or sub-polygonal with long, slightly tapering processes bifurcating in a sort of pinnate fashion; wall smooth.

DIMENSIONS (in microns): 20 specimens measured:

	Vesicle Diameter	Process Length	Process Basal Diameter
Range:	20-24	16-22	3.1-4.1
Mean:	22	20	3.5

LOCALITY: This species occurs commonly in all the wells studied.

ILLUSTRATED SPECIMENS:

Pl. XIX, fig. 5, Sample UC/19-2A/8480/1, Co-ordinate 117.8/23.4

Pl. XIX, fig. 7, Sample UC/19-2A/8480/4, Co-ordinate 123.5/48.0

Pl. XIX, fig. 8, Sample UC/19-2A/8480/3, Co-ordinate 123.3/24.0

OCCURRENCE AND STRATIGRAPHIC RANGE: This species has been previously recorded from the Wenlock Shale, Shropshire (Downie, 1963); La Vid

Shale (Devonian), NW Spain (Cramer, 1964); Calcaire d'Angers (Emsian), Anjou (Moreau-Benoit, 1967); Lower Devonian of the Moesian Platform, Romania (Beju, 1967) and the Wenlock and Ludlow Series, Shropshire (Lister, 1970).

Subgroup POLYGONOMORPHITAE Downie, Evitt and Sarjeant, 1963

Genus VERYHACHIUM Deflandre (1954), 1958, emend. Downie and Sarjeant, 1963

Type Species: Veryhachium trisulcum Deunff, 1954.

DIAGNOSIS: A genus of acritarchs having polygonal or sub-polygonal tests bearing a small number (in general 3-8) of hollow pointed spines with closed tips; size of text 10-40 microns, rarely smaller or greater.

VERYHACHIUM TRISPINOSUM (Eisenack, 1938) Cramer, 1964

Plate XXI, Figures 1-8

1938: Hystrichosphaeridium trispinosum Eisenack, Z. f. Gesch., 14, p. 16, figs. 2, 3.

1954: Veryhachium trispinosum (Eisenack) Deunff, C.R.S. Soc. Géol. Fr., 11, p. 240, fig. 2.

1964: Veryhachium trispinosum (Eisenack) Cramer, Leidse Geol. Med., 30, p. 304, Pl. VIII, text-fig. 26

REMARKS: The "formgroup" of V. trispinosum covers the following species and their transitional forms (Cramer, op. cit): V. reductum (Deunff, 1959), V. downie Stockmans and Willière, 1962; V. trisulcum Deunff, 1959; V. trispinosum (Eisenack, 1931); V. geometricum (Deflandre, 1942). The size range of this group observed in the Ghanaian sediments is 18-40 microns (longest side of vesicle, excluding processes).

ILLUSTRATED SPECIMENS:

Pl. XXI, fig. 1, Sample UC/19-2A/9010/1, Co-ordinate 126.1/64.8

Pl. XXI, fig. 2, Sample A-1/14C/2, Co-ordinate 118.7/27.8

Pl. XXI, fig. 3, Sample A-1/14C/1, Co-ordinate 112.4/31.9

Pl. XXI, fig. 4, Sample UC/19-2A/9010/1, Co-ordinate 122.9/31.0

Pl. XXI, fig. 5, Sample UC/19-2A/8480/2, Co-ordinate 120.4/61.3

Pl. XXI, fig. 6, Sample UC/19-2A/8480/2, Co-ordinate 120.4/61.3

Pl. XXI, fig. 7, Sample UC/19-2A/8480/1, Co-ordinate 125.2/51.8

Pl. XXI, fig. 8, Sample UC/19-2A/7550/1, Co-ordinate 125.1/47.4

LOCALITY: This species occurs commonly to abundantly in all the three wells studied.

OCCURRENCE AND STRATIGRAPHIC RANGE: This formgroup has been reported from various Paleozoic sediments. It is long-ranging and has little stratigraphic value.

VERYHACHIUM EUROPAEUM (Stockmans and Willière, 1962) Cramer, 1964

Plate XXI, Figures 9, 10

1962: *Veryhachium europaeum* Stockmans and Willière, Bull. Soc. Belg. Geol., 71, p. 85, Pl. 1, fig. 6.

1964: *Veryhachium europaeum* (Stockmans and Willière, 1962) Cramer, Leidse Med., 30, p. 306, Pl. IX, figs. 4, 6, 7, 8.

REMARKS: This "formgroup" covers the following species and their transitional forms (Cramer, *op. cit.*): *V. europaeum* Stockmans and Willière, 1962; *V. europaeum* (Stockmans and Willière) Wall and Downie, 1963; *V. legrandi* Stockmans and Willière, 1962; *V. flagelliferum* Wall and Downie, 1963. The size range of this "formgroup" observed in the Ghanaian sedi-

ments is 15-35 microns (longest side of vesicle, excluding processes).

ILLUSTRATED SPECIMENS:

Pl. XXI, fig. 9, Sample UC/19-2A/8480/1, Co-ordinate 125.2/51.8

Pl. XXI, fig. 10, Sample UC/19-2A/8480/3, Co-ordinate 112.0/20.5

LOCALITY: This formgroup occurs commonly to abundantly in all the wells.

OCCURRENCE AND STRATIGRAPHIC RANGE: This "formgroup" has been reported from various Paleozoic sediments. It is long ranging and has little stratigraphic value.

VERYHACHIUM STELLIGERUM Deunff, 1957

Plate XIX, Figure 12

1957: Veryhachium stelligerum Deunff, Bull. Soc. Géol. Miner. Bretagne, p. 10, fig. 10.

1964: Veryhachium stelligerum Deunff, Cramer, Leidse Geol. Med., 30, Pl. XI, figs. 12-15; text-fig. 28:4-6.

DESCRIPTION: Test star-shaped; processes five or six all in one plane; tips of processes blunt; wall granular; a slit-like opening occurs in the central portion of the test in many specimens.

DIMENSIONS (in microns): 20 specimens measured.

	Test Total Diameter	Process Length	Process Basal Diameter
Range:	35-50	13-20	6.2-8.3
Mean:	39	15	7.1

ILLUSTRATED SPECIMEN:

Sample UC/19-2A/8480/4, Co-ordinate 126.1/51.2

LOCALITY: This species occurs commonly in all the three wells.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species has been reported from the Middle Devonian, Canada (Deunff, 1957); Frasnian, Belgium (Stockmans and Willière, 1962); and Lower Devonian (Emsian), NW Spain (Cramer, 1964).

VERYHACHIUM LAIRDI (Deflandre, 1946) Deunff, 1958

Plate XXIII, Figure 5

1946: *Hystrichosphaeridium lairdi* Deflandre, Fich. Micropal., 8(257), fig. 112.

1958: *Veryhachium lairdi* (Deflandre) Deunff, Bull. Soc. Géol. Min. Bretagne, p. 28, Pl. 8, figs. 75-79

1963: *Veryhachium lairdi* (Deflandre) Stockmans and Willière, Bull. Soc., 71 Belg. Géol., p. 454, Pl. 3, fig. 5, text-fig. 7.

1964: *Veryhachium lairdi* (Deflandre) Deunff, 1958, Cramer, Leidse Geol. Med., 30, p. 309. Pl. XI, fig. 16; Pl. XII, figs. 1, 2; text-fig. 27:10, 11.

1967: *Veryhachium lairdi* (Deflandre), Beju, Rev. Palaeobot. Palynol., 5(1-4), p. 45, Pl. II, fig. 5.

DESCRIPTION: Vesicle sub-square to rectangular, hollow, with four long tapering processes situated at the corners; wall smooth.

DIMENSIONS (in microns): 10 specimens measured.

	Vesicle Longest Side	Vesicle Shortest Side	Process Length	Process Basal Diameter
Range:	18-20	13-15	34-40	2-3
Mean:	19	14	38	3

ILLUSTRATED SPECIMEN:

Sample SE/10-1/8600/1, Co-ordinate 122.6/61.2

LOCALITY: This species occurs commonly in all the three wells.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species has been reported from various Ordovician, Silurian and Devonian sediments in various regions.

VERYHACHIUM sp. cf. V. LAIRDI Deflandre

Plate XIX, Figures 13, 14

Plate XXI, Figure 13

DESCRIPTION: Test sub-square to rectangular with four tapering processes situated at the corners; occasionally, a fifth process is present and is situated at the center of the test; the processes are short with blunt tips; wall is smooth or finely granular.

DIMENSIONS (in microns): 20 specimens measured.

	Vesicle Longest Side	Process Length	Process Basal Diameter
Range:	13-18	8-10	4.5-5.2
Mean:	15	9	4.8

ILLUSTRATED SPECIMENS:

Pl. XIX, fig. 13, Sample UC/19-2A/8480/1, Co-ordinate 120.3/50.7

Pl. XIX, fig. 14, Sample UC/19-2A/8480/2, Co-ordinate 122.2/43.2

Pl. XXI, fig. 13, Sample A-1/14C/1, Co-ordinate 119.7/27.8

LOCALITY: This species occurs commonly in all the three wells.

REMARKS: This species differs from *V. lairdi* Deflandre which was also observed from the Ghanaian sediments by its short and blunt tipped processes and granular ornamentation observed in some specimens.

VERYHACHIUM PASTORIS Deunff, 1966

Plate XXI, Figures 14, 15

Plate XXIII, Figure 1

1966: *Veryhachium pastoris* Deunff, Soc. Geol. France, Compte Rendu 1, p. 22, Pl. 1, fig. 4

DESCRIPTION: Vesicle polygonal, star-shaped, inflated; central area formed by fusion of broad bases of six processes; process tips blunt; wall granular.

DIMENSIONS (in microns); 10 specimens measured.

	Longest Side	Process Length
Range:	130-150	52-64
Mean:	144	57

ILLUSTRATED SPECIMEN:

Pl. XXI, fig. 14, Sample UC/19-2A/8500/4, Co-ordinate L110.6/51.2

Pl. XXI, fig. 15, Sample UC/19-2A/8950/4, Co-ordinate 123.4/54.6

Pl. XXIII, fig. 1, Sample UC/19-2A/8950/4, Co-ordinate 122.2/54.6

LOCALITY: This species was observed from all the three wells, but are rare.

OCCURRENCE AND STRATIGRAPHIC RANGE: Deunff (1966) recorded this species

from the Upper Devonian of Tunisia.

REMARKS: The Ghanaian specimens of this species are similar to the Tunisian specimens in the star-like shape of the test.

VERYHACHIUM RABIOSUM Cramer, 1964, restricted

Plate XXIII, Figure 4

1964: Veryhachium rabiosum Cramer, Leidse Geol. Med., 30, p. 299, Pl. VII, 5, 8, not Pl. V, fig. 7, Pl. VI, figs. 3, 8, Pl. VII, fig. 9.

DISCUSSION: Cramer (op. cit.) diagnosed Veryhachium rabiosum Cramer as follows:

> "The species is rather variable in outline. The central body is made up by fusion of the very broad bases of the processes. These processes may be simple, or bifurcate at the tips. They end in a rounded tip. In pure forms the central body is sub-square to octahedral, dorsoventrally compressed. Number of processes four to ten, usually four to six. The wall is simple, thick. In pure forms it shows a scabrate to rugulate structure in a pattern that is roughly parallel to the direction of the processes. The very tips of the processes are psilate. In forms that are intermediate to B. molinum n. sp. the wall is less transparent and thicker, it lacks the scabrate or fugulate structure; the wall is psilate in pure forms of B. Molinum n. sp. 'Dimensions up to 150 microns, rarely more'."

Lister (1970, p. 69) included V. rabiosum Cramer in Evittia remota (Deunff, 1955) Lister, together with various species of Veryhachium with branching processes and granular to echinate sculpture.

The diagnosis of Evittia Brito, 1967, as emended by Lister (1970, p. 66) is as follows:

> "Vesicle hollow, sub-spherical to polygonal, single-walled; vesicle wall may be smooth or sculptured; processes are heteromorphic, hollow, invariably granular to echinate, communicating freely with the vesicle cavity. Excystment by cryptosure, apical or near equatorial."

Thus, according to the emended diagnosis of the genus

Evittia, acritarchs with simple, unbranched processes appear to fall outside the definition of the genus Evittia.

In the Ghanaian Devonian sediments acritarchs with simple and branched processes, granular to echinate ornamentations very closely similar to V. rabiosum Cramer were observed; those with branched processes have been designated E. remota (Deunff) Lister, 1970 and those with unbranched processes have been designated V. rabiosum Cramer, restricted.

DESCRIPTION: Vesicle tetrahedral shaped, formed by fusion of the broad bases of the processes; processes; processes simple; process tips blunt, rounded; surface of test granular to echinate.

DIMENSIONS (in microns): 20 specimens measured.

	Total Diameter
Range:	100-170
Mean:	14

ILLUSTRATED SPECIMEN:

Sample UC/19-2A/8480/4, Co-ordinate 124.6/61.5

LOCALITY: This species occurs commonly in all the three wells studied.

Genus ESTIASTRA Eisenack, 1959

Type species: Estiastra magna Eisenack, 1959

DIAGNOSIS: Test star-shaped with wide cone-shaped appendices originating from a common centre; no distinct central body which can be distinguished from the appendices; but the central area may be formed by the

fusion of the broad bases of the cone-shaped appendices.

ESTIASTRA sp.

Plate XXIV, Figure 1

DESCRIPTION: Test polygonal, inflated, formed by fusion of broad bases of four (observed) cone-shaped processes; process tips sharp and pointed; wall smooth.

DIMENSION (in microns): 10 specimens measured.

	Vesicle Longest Side	Process Length	Process Diameter at Base
	108	62	45
Range:	100-114	58-64	40-50
Mean:	108	62	45

ILLUSTRATED SPECIMEN:

Sample UC/19-2A/8480/3, Co-ordinate 126.4/24.1

LOCALITY: This species occurs sparingly in all the three wells.

Genus STELLINIUM Jardiné et al., 1972

Type species: Veryhachium octoaster Staplin, 1961.

DIAGNOSIS: Test hollow, polyderal, star-shaped in outline, with 8 to 12 more or less long, separate, hollow appendages at the corners; appendages arranged more or less in two planes; each appendage of a triangular section is connected to three contiguous appendages, their junction formed by radial crests.

STELLINIUM OCTOASTER (Staplin) Jardiné et al., 1972

Plate XXI, Figure 12

Plate XXII, Figure 3

1961: Veryhachium octoaster Staplin, Paleont., 4(3), p. 413, Pl. 49, figs. 3-4.

1968: Veryhachium octoaster Staplin, Jardiné and Yapaudjian, Rev. Inst. Fr. Pétrole, XXIV (4), p. 464, Pl. 4, figs. 10, 12.

1969: Veryhachium octoaster Staplin, Lanzoni and Magloire, Inst. Fr. Pétrole, XXIV (4), p. 468, Pl. VIII, figs. 6, 7.

1972: Stellinium octoaster (Staplin) Jardiné et al., Compte Rendu, 1, p. 298, Pl. 2, figs. 1, 2.

DESCRIPTION: Test hollow, polyhedral, star-shaped in outline; central portion formed by a fusion of eight or less triangular shaped processes; processes in more or less two planes; each process of a triangular section is connected to three contiguous processes, their function formed by radial crests.

DIMENSIONS (in microns): 10 specimens measured.

	Longest Side
Range:	72-104
Mean:	88

ILLUSTRATED SPECIMENS:

Pl. XXI, fig. 12, Sample UC/19-2A/8480/3, Co-ordinate 120.3/44.5

Pl. XXII, fig. 3, Sample UC/19-2A/8480/1, Co-ordinate 109.4/61.0

LOCALITY: This species occurs sparingly in all the three wells studied.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first described from the Upper Devonian (Frasnian) in Alberta, Canada (Staplin, 1961). The species has also been recorded from the Lower to Middle Devonian (Emsian-Frasnian) in the Sahara (Jardiné and Yapaudjian, 1968); Upper Devonian (Famenian) in the Sahara (Lanzoni and Magloire), and from Middle Devonian in Algeria, and Devonian in Tunisia (Jardiné et al. 1972). The stratigraphic range of the species is probably Lower Devonian to Upper Devonian.

REMARKS: The Ghanaian specimens of this species are essentially similar to other specimens recorded elsewhere.

Subgroup PTEROMORPHITAE Downie, Evitt and Sarjeant, 1963

Genus PTEROSPERMOPSIS W. Wetzel, 1952

Type species: Pterospermopsis danica Wetzel, 1952.

DIAGNOSIS: Vesicle circular in outline, surrounded by a diaphanous membrane extended as a flange. This flange is not supported by rods or spokes, although short stiffening processes, radial thicknings or flutings are developed in some species.

PTEROSPERMOPSIS sp. 1

Plate XXIV, Figure 4

DESCRIPTION: Vesicle circular in outline, thick, surrounded by thin, transparent diaphanous membrane extended as a flange; this flange is

radially folded.

DIMENSIONS (in microns): 10 specimens measured.

	Total Diameter	Vesicle Diameter	Flange Radius
Pl. XXIV, fig. 4	125	47	39
Range:	100-130	30-50	30-40
Mean:	118	40	35

ILLUSTRATED SPECIMEN:

Sample UC/19-2A/8480/1, Co-ordinate L111.3/11.8.

LOCALITY: This species occurs in all the three wells but is rare.

Genus VILIFERITES Brito, 1967

Type species: *Viliferites tenuimarginatus* Brito, 1967

DIAGNOSIS: Vesicle usually nearly square, smooth, with a short, occasionally bifurcate process at the corners; a smooth transparent membrane surrounds the vesicle in its equatorial plane; size of the central body about 25 microns to 30 microns; maximum width of the membrane about 7 microns at a point between the corner processes, which are apparently solid and measure about 5 microns in length.

VILIFERITES TENUIMARGINATUS Brito, 1967

Plate XXVI, Figures 1-11.

1967: *Viliferites tenuimarginatus* Brito, Micropaleo.,13(4), p. 477, Pl. 1, figs. 4-8

DESCRIPTION: Vesicle nearly square or polygonal, smooth or ornamented with sort of granular or rugulate-like patterns; corners of vesicle extended to form bifurcate processes; a smooth transparent membrane surrounds the vesicle in its equatorial plane; a slit-like opening may occur in some specimens.

DIMENSIONS (in microns): 20 specimens measured.

	Total Diameter Including Outer Membrane	Vesicle (Central Body) Diameter
Range:	40-52	36-40
Mean:	48	38

ILLUSTRATED SPECIMENS:

Pl. XXVI, fig. 1, Sample A-1/14C/2, Co-ordinate 123.4/38.2

Pl. XXVI, fig. 2, Sample A-1/14C/1, Co-ordinate 115.3/39.8

Pl. XXVI, fig. 3, Sample A-1/14C/1, Co-ordinate 115.0/43.7

Pl. XXIV, fig. 4, Sample A-1/14C/2, Co-ordinate 124.2/35.2

Pl. XXIV, fig. 5, Sample A-1/14C/1, Co-ordinate 110.7/36.7

Pl. XXIV, fig. 6, Sample A-1/14C/1, Co-ordinate 115.4/39.8

Pl. XXIV, fig. 7, Sample UC/19-2A/8480/4, Co-ordinate 121.8/47.6

Pl. XXIV, fig. 8, Sample UC/19-2A/8480/1, Co-ordinate 113.9/45.7

Pl. XXIV, fig. 9, Sample UC/19-2A/8480/2, Co-ordinate 114.0/19.4

Pl. XXIV, fig. 10, Sample UC/19-2A/8480/2, Co-ordinate 116.2/56.0

Pl. XXIV, fig. 11, Sample UC/19-2A/8480/2, Co-ordinate 120.0/29.2

LOCALITY: This species was found in all the three wells, but occurs commonly in the Atiavi-1 well in Sample 14C at about 3,239 feet.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was described from Palynological Zone R (Lower Devonian?) in the Maranhão Basin, Brazil (Brito, 1967).

REMARKS: The Ghanaian specimens of this species are essentially similar to the Brazilian specimens, however, the vesicles of some of the Ghanaian specimens are distinctly ornamented with granular or rugulate-like patterns. Besides, some of the specimens have slit-like opening across the vesicles. The overall diameter of the Ghanaian specimens is 40-52 microns and the diameter of the vesicle (central body) is 36-40 microns. This compares with 25-30 microns for the diameter of the central body recorded for the Brazilian specimens by Parito (op. cit.)

Subgroup HERKOMORPHITAE Downie, Evitt and Sarjeant, 1963

Genus CYMATIOSPHAERA O. Wetzel, 1933, emend. Deflandre, 1954

Type species: Cymatiosphaera radiata O. Wetzel, 1933

DIAGNOSIS: Shell of organic material, often brown, globular (Spherical or elliptical) whose external surface is divided into polygonal fields by membranes perpendicular to the surface. Points of junction of membrane (angles or polygons) usually thickened, and giving in lateral view the impression of small sticks or columns. No points or spines. Margins of the membrane often distinct and parallel to the shell surface, sometimes a little concave to torn or corroded. Shell surface smooth or punctate or supplied with granules. Size from a few to several dozen microns. Sometimes 100 microns, crest included.

?CYMATIOSPHAERA spp.

Plate XX, Figures 11, 12

REMARKS: These specimens occur commonly in the marine sections of the various wells studied. The specimens are characterized by spheroidal vesicles which are divided, either fully or partially into polygonal and sub-polygonal areas. The diameter of these specimens varies from 60-80 microns.

ILLUSTRATED SPECIMENS:

Pl. XX, fig. 11, Sample UC/19-2A/8480/3, Co-ordinate 115.4/59.3

Pl. XX, fig. 12, Sample SE/10-1/8650/3, Co-ordinate 118.4/33.4

Subgroup NETROMORPHITAE Downie, Evitt and Sarjeant, 1963

Genus LEIOFUSA Eisenack, 1938

Type species: *Ovum hispidum fusiformis* Eisenack, 1934

DIAGNOSIS: Test oval, elongate to fusiform with smooth, striate, granulate or psilate walls; generally smaller than 500 microns.

LEIOFUSA FASTIDIONA Cramer, 1964

Plate XXIV, Figure 2

1964: *Leiofusa fastidiona* Cramer, Leidse Geol. Med., 30, p. 324, Pl. VI, fig. 6; Pl. XIX, fig. 5, text-fig. 33:9.

DESCRIPTION: Vesicle, hollow, elongated fusiform with blunt ends; wall granular to echinate.

DIMENSIONS (in microns): 20 specimens measured.

	Total Length	Maximum Diameter
Range:	78-125	8.3-14.6
Mean:	100	12.5

ILLUSTRATED SPECIMEN:

Sample A-1/14C/3, Co-ordinate 125.6/32.8

LOCALITY: This species was found from the Atiavi-1 well at about 3,239 feet. It was not observed from the other wells.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was described from the La Vid Shale (Middle Siegenian to Emsian), NW Spain (Cramer, 1964).

REMARKS: Cramer (op. cit.) indicated that the wall of the Spanish specimens of this species is psilate at 1200X magnification except for a greater number of small echinae (smaller than one micron) that are irregularly distributed over the body, and that the echinae occur in a relatively greater number at the poles. In the Ghanaian specimens, however, the wall is uniformly ornamented with coarse granules to echinate which are quite apparent under magnification lower than 1000X. The total length of the Spanish specimens is about 70 microns compared with 78-125 microns recorded for the Ghanaian specimens.

LEIOFUSA sp. 1

Plate XXIV, Figure 3

DESCRIPTION: Vesicle hollow elongate, fusiform with the central portion

sub-ovoid to sub-cylindrical, and rapidly tapering to thin spine-like processes at the poles; wall smooth.

DIMENSIONS (in microns): One specimen measured.

Total Length	Maximum Diameter
186	46.5

ILLUSTRATED SPECIMEN:

Sample UC/19-2A/9010/4, Co-ordinate 124.8/49.0

LOCALITY: This species occurs in all three wells but is rare.

?LEIOFUSA sp. 2

Plate XXIV, Figure 8

DESCRIPTION: Test hollow, sub-cylindrical, bifurcating at opposite ends; wall thin, translucent, granular; tips sharply pointed, closed.

DIMENSIONS (in microns): One specimen measured.

	Total Length	Maximum Diameter	Process Length
Pl. XXIV, Fig. 8	226	22	52

ILLUSTRATED SPECIMEN:

Sample SE/10-1/8450/3, Co-ordinate 121.0/21.0

LOCALITY: This species was observed only from the SE/10-1 well between 8,400-9,050 feet depth. It is very rare.

Genus NAVIFUSA Combaz, Lange and Pansart, 1967

Type species: Leiofusa navis (Eisenack, 1938)

DIAGNOSIS: Test in the shape of a more or less elongate ellipsoid, or of a rod with rounded extremities, without appendages; membrane simple, smooth or ornamented.

NAVIFUSA BRASILIENSIS (Brito and Santos, 1965) Combaz *et al*. 1967

Plate XXVII, Figures 1-3

1965: Leiofusa braziliensis Brito and Santos, Notas Prelim. Estud., p. 12, fig. 13.

1967: Leiofusa brasiliensis Brito and Santos, Brito, Micropaleo., 13(4), p. 481, Pl. 2, fig. 5.

1967: Navifusa brasiliensis (Brito and Santos) Combaz, Lange and Pansart, Rev. Paleobot. Palynol., 1(1-4), p. 295, Fig. 1.

1967: Navifusa cf. N. brasiliensis (Brito and Santos) Combaz, Lange and Pansart, Lange, Bol. Paranaense Geociências, 21/22, p. 85, Pl. 5, fig. 52.

DESCRIPTION: Test elongate with rounded extremities; ratio of length to width about 2.3 to 5.2; wall smooth or granular.

DIMENSIONS (in microns): 20 specimens measured.

	Total Length	Maximum Width	Length / Width
Range:	152-209	41-66	2.3-5.2
Mean:	182	47	3.7

ILLUSTRATED SPECIMENS:

Pl. XXVII, fig. 1, Sample UC/19-2A/8480/4, Co-ordinate 112.4/61.2

Pl. XXVII, fig. 2, Sample UC/19-2A/8480/3, Co-ordinate 120.2/37.4

Pl. XXVII, fig. 3, Sample UC/19-2A/8480/3, Co-ordinate 114.8/57.4

LOCALITY: This species occurs commonly in all the three wells studied.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first described from the Devonian of the Maranhão Basin, Brazil, by Brito and Santos. Lange (1967) has observed the species restricted to Middle and upper Devonian sediments in the Paraná Basins, Brazil.

REMARKS: The Ghanaian specimens of this species are closely similar to the Brazilian specimens.

NAVIFUSA EISENACKI (Brito and Santos, 1965), Combaz *et al.*, 1967

Plate XXVII, Figures 4, 5, 7

1967: *Navifusa eisenacki* (Brito and Santos), Combaz, Lange and Pansart, Rev. Palaeobot. Palynol.,1(1-4), p. 295, Fig. 1

1967: *Navifusa* cf. *N. eisenacki* (Brito and Santos, 1965), Lange, Bol. Paranaeuse Geociências,21/22, p. 86, Pl. 5, fig. 53

REMARKS: This species is closely similar to *N. brasiliensis* but has larger length/width ratio--from about 6.6 to 14.0 for 20 specimens measured. This compares with 5.5 to 15 length/width ratio recorded for the Brazilian specimens by Brito and Santos (*in* Lange, 1967, p. 86).

DIMENSIONS (in microns): 20 specimens measured.

	Total Length	Maximum Width	Length Width
Range:	209-305	20-31	6.6-14.0
Mean:	242	24	9.2

ILLUSTRATED SPECIMENS:

Pl. XXVII, fig. 4, Sample UC/19-2A/8480/1, Co-ordinate 109.6/54.0

Pl. XXVII, fig. 5, Sample UC/19-2A/8480/4, Co-ordinate 110.0/28.9

Subgroup SCUTELLOMORPHITAE Brito, 1966

Genus MARANHITES Brito, 1965, emend. Daemon, Quadros and da Silva, 1967

Type species: Maranhites brasiliensis Brito, 1965.

EMENDED DIAGNOSIS: Flattened grains circular, originally oblate; forms generally biplane--symmetrical and asymmetrical; size ranging from approximately 50 microns to about 200 microns; some specimens have a ring-shaped thickening in their center.

On the periphery the grains show a concave indenture with thickened borders of the tegument, which can vary from a continuous crenulation to the formation of dark and dense isolated zones of various sizes, and of circular to semi-circular shape when observed from above; sometimes one of these elements may present a considerably greater development than that of the others; in many specimens these denser zones appear as a cluster of fused smaller zones.

Transparent bladders can be noted embedded in these dense zones, at times advancing beyond the surface of the individual speciman. In some forms, when examined in profile, the bladder appears as a small elevation due to the flattening of the specimen.

The bladders can vary from vestigial to isolated thick, transparent bladders; their number can range from two to approximately

forty; these morphological differences result in an enormous variety in the genus; some bladders, when examined under immersion, suggest a slight reticulation.

MARANHITES BRASILIENSIS (Brito, 1965)

Form A Daemon et al., 1967

Plate XXVIII, Figure 2

1965: Maranhites brasiliensis Brito, Univ. BA. Esc. Geol. 2(2), Pl. 1, fig. 1.

1967: Maranhites brasiliensis Brito, Micropaleo., 13(4), p. 481, Pl. 2, fig. 11.

1967: Maranhites brasiliensis Form A, Daemon et al., Bol. Paranaense Geociências, 21/22, p. 120, Pl. 4, Form A.

DESCRIPTION: Grain flattened, circular; edge crenulated.

DIMENSIONS (in microns): 20 specimens measured.

	Diameter
Range:	80-135
Mean:	108

ILLUSTRATED SPECIMENS:

Sample SE/10-1/8700/1, Co-ordinate 120.6/30.4

LOCALITY: This form of the species occurs commonly in all the three wells studied.

OCCURRENCE AND STRATIGRAPHIC RANGE: This form of the species occurs commonly in Middle to Upper Devonian sediments in Brazil.

REMARKS: The Ghanaian specimens of this form are closely similar to the Brazilian specimens.

MARANHITES BRASILIENSIS (Brito, 1965)

Form P Daemon *et al.*, 1967

Plate XXVIII, Figure 3

1966: *Tapajonites mosesii* (Sommer), Sommer and van Boekel, Moreau-Benoit, Rev. Micropaléo., 8(4), p. 226, Pl. 3, figs. 57-58.

1967: *Maranhites mosesii* (Sommer), Brito, Micropaléo., 13(4), p. 481, Pl. 2, fig. 12

1967: Form P (*Maranhites* [ex *Tapajonites*] *mosesii*) Daemon *et al.*, Bol. Paranaense Geociências, 21/22, p. 12, Pl. 4, Form P

1969: Tapajonites mosesii (Sommer) Sommer and van Boekel, Lanzoni and Magloire, Inst. Fr. Pétrole, XXIV(4), p. 468, Pl. VIII, fig. 14.

DESCRIPTION: Grain flattened, circular; edge ornamented by a few (usually three isolated, semicircular shaped "processes" with a similar circular shaped "process" in the central portion of the grain.

DIMENSIONS (in microns): 10 specimens measured.

	Diameter
Range:	75-120
Mean:	95

ILLUSTRATED SPECIMEN:

Sample UC/19-2A/8480/2, Co-ordinate 124.3/112.4

LOCALITY: This form of the species occurs in all the three wells but is rare.

OCCURRENCE AND STRATIGRAPHIC RANGE: This form has been reported from Devonian sediments in various sedimentary basins in Brazil. In the

Maranhão Basin, Brito (1967) recorded it from palynological zones Middle Devonian to Upper Devonian. In the Amazon Basin, the form has been recorded from the Barreirinha Member (lowest member of the Curuá Formation) Upper Devonian (Frasnian) and in the Paraná Basin, the species also appears to be restricted to the Upper Devonian (Frasnian) according to Daemon *et al*. (1967). Moreao-Benoît (1966) recorded the form from the Upper Devonian to Lower Carboniferous in the Sahara, and Lanzoni and Magloire (1969) have reported it restricted to the Upper Devonian-Lower Carboniferous sediments in the Sahara.

REMARKS: The Ghanaian specimens of this form of the species are closely similar to other specimens recorded elsewhere.

Subgroup uncertain

Genus TRIANGULINA Cramer, 1964

Type species: *Triangulina alargada* Cramer, 1964

DIAGNOSIS: Acritarchs with a triangular somewhat inflated inner body, surrounded by an outer body of approximately the same shape, but with hollow processes at the corners.

TRIANGULINA ALARGADA Cramer, 1964

Plate XXV, Figures 5, 6

1964: *Triangulina alargada* Cramer, Leidse Geol. Med., 30, p. 334, Pl. VI, figs. 1, 4; Text-fig. 39.

1967: *Triangulina alargada* Cramer, 1964, Brito, Micropaléo., 13(4), p. 478, Pl. 1, figs. 8, 9.

1971: Triangulina cf. T. alargada Cramer, 1964, Legault, Unpub. Ph.D. Thesis, p. 188, Pl. XV, fig. 12.

DIMENSIONS (in microns): 5 specimens measured.

Outer Body Longest Side (Including Processes)	Inner Body Longest Side (Excluding Processes)
112	88

ILLUSTRATED SPECIMENS:

Pl. XXV, Fig. 5; Sample A-1/14C/1, Co-ordinate 117.9/43.4

Pl. XXV, Fig. 6, Sample UC/19-2A/8480/3, Co-ordinate 117.2/58.2

LOCALITY: This species occurs sparingly in all the three wells studied.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first described from the Lower Devonian (Emsian) of NW Spain (Cramer, 1964). The species has also been observed from the Lower Devonian of Brazil (Brito, 1967) and the Middle Devonian Hamilton Group in southern Ontario (Legault, 1971).

REMARKS: The inner bodies of all the specimens of this species observed from Ghana are moderately transparent. Cramer (op. cit.) however indicated that the inner bodies of some of the Spanish specimens were not transparent. The general shape of the vesicle of the Ghanaian specimens are closely similar to other specimens of the species recorded elsewhere.

Genus TUNISPHAERIDIUM Deunff and Evitt, 1968

Type species: Tunisphaeridium concentricum Deunff and Evitt, 1968

DIAGNOSIS: Acritarchs with an overall spherical to ellipsoidal or pyriform outline composed of a central sphaeroidal vesicle bearing numerous rodlike, apparently solid, processes whose extremities are interconnected by a diaphanous membrane alone, by a membrane reinforced with a network of faint to conspicuous filaments. No pylome observed.

TUNISPHAERIDIUM CONCENTRICUM Deunff and Evitt, 1968

Plate XXV, Figure 2

1968: Tunisphaeridium concentricum Deunff and Evitt, Stanford Univ. Publ. Geol. Sci., XII(1), p. 3, Pl. 1, figs. 1-12.

1971: Tunisphaeridium concentricum Deunff and Evitt, 1968, Legault, Unpubl. Ph.D. Thesis, p. 192, Pl. XVI, figs. 2-7.

DESCRIPTION: Vesicle spherical; processes solid, rodlike, numerous, essentially equal lengths, expanded at their tips which are interconnected by a network of filaments or thin membrane; no pylome observed.

DIMENSIONS (in microns): 10 specimens measured.

	Total Diameter	Vesicle Diameter	No. of Processes	Process Length
Range:	80-100	35-43	>12	30-36
Mean:	88	38		32

ILLUSTRATED SPECIMEN:

Pl. XXV, Fig. 2, Sample SE/10-1/8450/4, Co-ordinate 116.2/39.0

LOCALITY: This species was observed in all the three wells studied.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first described from Middle Silurian sediments in New York, North America by Deunff and Evitt (op. cit.). The species has also been recorded from the Middle Devonian Hamilton Group in southern Ontario, Canada (Legault, Unpubl. Ph.D. Thesis).

REMARKS: The Ghanaian specimens of this species are generally similar to the North American specimens, however, the number of processes observed are generally fewer and the filaments much finer.

TUNISPHAERIDIUM CAUDATUM Deunff and Evitt, 1968

Plate XXIV, Figures 6, 7

Plate XXV, Figure 1

1968: Tunisphaeridium caudatum Deunff and Evitt, Stanford Univ. Publ. Geol. Sci., XII(1), p. 4, Pl. 2, fig. 1-4.

DESCRIPTION: Vesicle spherical to ellipsoidal, processes solid, rodlike, numerous with uniform lengths; a single or a small group of neighbouring processes being conspicuously longer than most of the rest of the processes; these latter processes are of uniform length but occasionally a few transitional forms occur; the longest processes(es) distinctly differ from the rest by having a whiplike termination which are also associated with fine radiating filaments; no pylome observed.

DIMENSIONS (in microns): 10 specimens measured.

	Total Diameter	Vesicle Diameter	No. of Processes	"Short" Process Length	"Long" Process Length
Range:	100-140	30-50	>20	15-25	30-40
Mean:	130	42		18	36

ILLUSTRATED SPECIMENS:

Pl. XXIV, fig. 6, Sample UC/19-2A/8480/1, Co-ordinate 121.0/57.3

Pl. XXIV, fig. 7, Sample UC/19-2A/8480/1, Co-ordinate 127.1/60.0

Pl. XXV, fig. 1, Sample SE/10-1/8600/3, Co-ordinate 118.7/31.4

LOCALITY: This species was observed from all the three wells studied.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species was first reported from the Middle Silurian of New York and Lower Devonian (Gedinnian) of Tunisia (Deunff and Evitt, 1968).

REMARKS: The Ghanaian specimens of this species are essentially similar to the North American and North African specimens.

Genus UMBELLASPHAERIDIUM Jardiné *et al.*, 1972

Type species: *Umbellasphaeridium saharicum* Jardiné *et al.*, 1972

DIAGNOSIS: Central body spherical or sub-spherical with a simple structureless wall more or less thickened and rigid; processes cylindrical at the base, flared terminally into a funnel shape. Diameter of central body 25 to 50 microns; length of processes 6 to 50 microns.

UMBELLASPHAERIDIUM SAHARICUM Jardiné et al., 1972

Plate XXV, Figure 3

1972: Umbellasphaeridium saharicum Jardiné et al., Compte Rendu, 1, p. 303, Pl. 2, figs. 11, 12; Pl. 3, fig. 1.

DESCRIPTION: Vesicle spherical with five cylindrical processes, flared at the extremities; wall smooth.

DIMENSIONS (in microns): 2 specimens measured.

	Vesicle Diameter	Process Length	Process Diameter at Base	Process Diameter (terminal portion)
Range:	37-41	24-35	3.8-4.2	20-24
Mean:	39	30	4.0	22

ILLUSTRATED SPECIMEN:

Pl. XXV, Fig. 3, Sample SE/10-1/7900/2, Co-ordinate 116.7/42.2

LOCALITY: This species is very rare; only two specimens were observed from the Signal Exploration and Development Company 10-1 well.

OCCURRENCE AND STRATIGRAPHIC RANGE: This species has been reported from Upper Devonian of the Sahara and Middle Devonian of Brazil (Jardiné et al., 1972, p. 303).

UMBELLASPHAERIDIUM sp. cf. U. SAHARICUM Jardiné et al., 1972

Plate XX, Figures 4, 7

REMARKS: These specimens are essentially similar to U. saharicum in the flared extremities of the processes. The processes of U. sp. cf. saharicum are more numerous (ten), as compared to five processes observed

in *U. saharicum*. Besides, the processes of *U.* sp. cf. *U. saharicum* are more elongated with smaller flared extremities as compared with those of *U. saharicum*.

DIMENSIONS (in microns): 4 specimens measured.

	Vesicle Diameter	Process Length	Process Diameter	Process Diameter Terminal Portion
Range:	40-45	36-43	3.0-3.8	10-15
Mean:	43	38	3.5	12

ILLUSTRATED SPECIMENS:

Pl. XX, fig. 4, Sample SE/10-1/8400, Co-ordinate 121.3/33.2

Pl. XX, fig. 7, Sample UC/19-2A/8150/2, Co-ordinate 114.0/33.4

LOCALITY: This species occurs in SE/10-1 and UC/19-2A wells but is rare.

FORMA G

Plate XXVI, Figures 12-15

DESCRIPTION: Test rounded, bowl shaped with a ring-like structure on one pole and a large aperture or opening on the opposite pole; wall thin, appears single layered; surface smooth.

DIMENSIONS (in microns): 10 specimens measured.

	Total Diameter	"Ring" Diameter	"Aperture" Diameter
Pl. XXVI, Fig. 14:	47	28	41
Range:	45-54	26-33	41-45
Mean:	47	31	43

ILLUSTRATED SPECIMENS:

Pl. XXVI, fig. 12, Sample A-1/14C/1, Co-ordinate 125.0/35.9

Pl. XXVI, fig. 13, Sample A-1/14C/2, Co-ordinate 117.5/45.7

Pl. XXVI, fig. 14, Sample A-1/14C/2, Co-ordinate 109.5/37.9

Pl. XXVI, fig. 15, Sample A-1/14C/1, Co-ordinate 116.7/28.0

LOCALITY: This form was observed only from Atiavi-1 well at about 3,239 feet depth.

FORMA H

Plate XXV, Figure 4

DESCRIPTION: Test hollow, inflated rectangular; wall thin, translucent, smooth; no opening observed.

DIMENSIONS (in microns): 3 specimens measured.

	Longest Side	Shortest Side
Range:	40-45	24-26
Mean:	42	25

ILLUSTRATED SPECIMEN:

Sample SE/10-1/8650/4, Co-ordinate 110.5/42.0

LOCALITY: This form was recovered only from the SE/10-1 well. It is very rare.

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APPENDIX

LITHOLOGIC DESCRIPTION OF CUTTING SAMPLES

Signal Exploration and Development Company/Ghana 10-1 Well

Depth in Feet	Lithologic Descriptions
6,010 - 6,040:	Reddish brown shale, occasional dark grey shale and coarse grained sandstone.
6,040 - 6,080:	Reddish brown shale and dark grey shale with increased proportion of coarse grained sandstone.
6,080 - 6,140:	Reddish brown shale, sandy; some basic igneous rock cuttings, probably from a thin dyke.
6,140 - 6,165:	Reddish brown, very coarse grained sandstone, grains well rounded mostly quartz, sorting very poor, cement argillaceous; basic igneous rock cuttings.
6,165 - 6,410:	Reddish brown, fine grained sandstone and reddish brown silty shale.
6,410 - 6,600:	Reddish brown silty shale with occasional dark grey shale, greenish shale, and fine grained argillaceous sandstone.

Depth in Feet	Lithologic Description
6,600 - 6,790:	Reddish brown very coarse grained sandstone, weakly calcareous, poorly sorted, occasional dark grey shale and greenshale.
6,790 - 6,800:	Greyish, coarse grained sandstone, calcareous, with greyish white chert.
6,800 - 6,920:	Creamy white fine grained sandstone with chert fragments and occasional carbonate pieces.
6,920 - 6,960:	Creamy white coarse grained sandstone and reddish brown silty shale.
6,960 - 7,130:	Reddish brown silty shale, weakly calcareous, and occasional coarse grained sandstone.
7,130 - 7,140:	Greyish white chert.
7,140 - 7,150:	Reddish brown fine grained sandstone and silty shale with coarse grained sandstone and chert fragments.
7,150 - 7,170:	Limestone, microgranular, creamy white.
7,170 - 7,200:	Dolomite, microgranular, creamy white.
7,200 - 7,240:	Pinkish brown argillaceous sandstone, medium grained, poorly sorted with reddish brown shale and chocolate brown shales.
7,240 - 7,260:	Dolomite, microgranular, creamy white.

Depth in Feet	Lithologic Description
7,260 - 7,310:	Reddish brown, argillaceous sandstone.
7,310 - 7,350:	Greyish white sandstone, medium grained, calcareous.
7,350 - 7,390:	Reddish brown sandy shale.
7,390 - 7,510:	Greyish white, sandstone, medium grained, weakly calcareous.
7,510 - 7,550	Reddish brown shaly sandstone.
7,550 - 7,590:	Dark grey shale.
7,590 - 7,610:	Dark grey shale, carbonaceous.
7,610 - 7,810:	Dark grey shale, shaly sandstone, and silty shale, occasionally reddish brown.
7,810 - 7,880:	Dark grey sandy shale and siltstone, occasionally medium grained porous sandstone with oil stains.
7,880 - 7,910:	Dark grey shale and siltstone.
7,910 - 7,940:	Greyish white sandstone, medium grained, porous, oil stained.
7,910 - 7,900:	Dark grey shale, sandy shale and siltstone; occasionally high proportion of red brown shale.
7,900 - 8,010:	Black shale, finely laminated.

Depth in Feet	Lithologic Description
8,010 - 8,090:	Dark grey shaly sandstone.
8,090 - 8,110:	Dark grey sandy shale and siltstone.
8,110 - 8,140:	Greyish black shale, laminated.
8,140 - 8,170:	Greyish silty shale grading into fine to medium grained sandy shale.
8,170 - 8,190:	Greyish fine to medium grained sandstone, calcareous.
8,190 - 8,210:	Greyish sandy shale and siltstone.
8,210 - 8,320:	Dark grey shale, finely laminated.
8,320 - 8,340:	Dark grey sandy shale, reddish brown sandy shale and siltstone.
8,340 - 8,580:	Dark grey to black shale, finely laminated, occasionally silty.
8,580 - 8,410:	Dark grey silty shale.
8,410 - 8,670:	Dark grey to black shale, finely laminated.
8,670 - 8,790:	Dark grey to red brown sandy shale, non-laminated, occasionally coarse grained, poorly sorted sandstone, pinkish and grey mottling.
8,790 - 8,820:	Dark grey to black shale.
8,820 - 8,930:	Dark grey sandy shale, occasionally silty.

Depth in Feet	Lithologic Descriptions
8,930 - 9,050	Greyish pink and pinkish brown mottled coarse grained sandstone with occasional dark grey shale. Note: The total depth of this well is supposed to 9,729 feet but the lower 675 feet thickness of the samples were not received from the company which drilled the well (Ghana Geol. Surv., personal communication).

Union Carbide/Ghana 19-2A Well

Depth in Feet	Lithologic Descriptions
6,640 - 6,950:	Pinkish brown, coarse grained, poorly sorted sandstone, calcareous, grains well rounded, occasional greyish shale and reddish brown shale, and cryptocrystalline greyish white chert.
6,950 - 6,970:	Reddish grey and chocolate brown micaceous sandy shale.
6,970 - 7,010:	Microcrystalline limestone, greyish white.
7,010 - 7,050:	Greyish white sandstone, very coarse grained, grains well rounded but poorly sorted, calcareous.
7,050 - 7,080:	Red sandstone, fine to coarse grained, poorly sorted, calcareous.
7,080 - 7,130:	Microcrystalline limestone, greyish white.
7,130 - 7,260:	Red sandy shale and siltstone, micaceous.
7,260 - 7,280:	Greyish sandstone, coarse to medium grained, calcareous.
7,280 - 7,370:	Very high proportion of basic igneous rock (dyke?), intermixed with greyish sandstone.
7,370 - 7,480:	Greyish sandstone, fine to medium grained, calcareous.
7,480 - 7,530:	Chocolate brown sandy shale.

Depth in Feet	Lithologic Descriptions
7,530 - 7,545:	Reddish coarse grained sandstone, grains well rounded, poorly sorted, weakly calcareous.
7,545 - 7,590:	Chocolate brown sandy shale.
7,590 - 7,660:	Chocolate brown fine grained shaly sandstone and siltstone.
7,660 - 7,690:	Chocolate brown fine grained sandstone, occasionally interbedded with sandy shale, micaceous.
7,690 - 7,770:	Chocolate brown sandy shale and siltstone, occasionally micaceous.
7,770 - 7,820:	Greyish sandstone, fine to medium grained, poorly sorted, weakly calcareous.
7,820 - 7,890:	Chocolate brown shale.
7,890 - 7,910:	Chocolate brown shale.
7,910 - 7,930:	Chocolate brown shaly sandstone.
7,930 - 7,950:	Chocolate brown shale to dark grey shale, carbonaceous.
7,950 - 7,960:	Greyish brown sandstone, medium grained, oil stained.
7,960 - 8,050:	Chocolate brown shale and dark grey shale.
8,050 - 8,160:	Dark grey silty shale, micaceous.
8,160 - 8,200:	Chocolate brown shale and dark grey shale.

Depth in Feet	Lithologic Descriptions
8,200 - 8,210:	Greyish white chert and carbonate fragments.
8,210 - 8,250:	Chocolate brown silty shale and dark grey shale.
8,250 - 8,310:	Chocolate brown silty shale, micaceous, occasionally greyish shale fragments.
8,310 - 8,550:	Dark grey to chocolate brown shale, laminated, occasionally sandy or silty.
8,550 - 8,570:	Greyish sandy shale.
8,570 - 8,700:	Chocolate brown and dark grey siltstones and shaly sandstone.
8,700 - 8,770:	Greyish white sandstone, coarse grained, very calcareous, poorly sorted, oil stained.
8,770 - 8,850:	Chocolate brown and dark grey silty shale, occasionally micaceous.
8,770 - 8,880:	Missing interval.
8,880 - 8,920:	Dark grey sandy shale.
8,920 - 8,940:	Greyish white sandstone, medium to coarse grained, weakly calcareous.
8,940 - 8,960:	Dark grey and chocolate brown sandy shale.
8,960 - 9,010:	Dark grey and chocolate brown shale.

Ghana Geological Survey A-1 Well

Depth in Meters	Lithologic Description
3,080 - 3,100:	Reddish brown shale, greyish white carbonate fragments.
3,100 - 3,110:	Chocolate brown sandstone, coarse to fine grained, poorly sorted.
3,100 - 3,170:	Chocolate brown and dark grey silty shale, siltstone, sandy shale, usually interbedded, micaceous, occasional thin sandstone.
3,870 - 3,910:	Yellowish grey sandstone, medium to fine-grained with occasional interbeddings of chocolate brown and dark grey silty shale.
3,910 - 3,940:	Reddish brown and chocolate brown sandy shale and siltstone.
3,940 - 3,950:	Greyish brown and creamy white sandstone, micaceous, poorly sorted.
3,950 - 3,990:	Chocolate brown and dark grey silty shale, micaceous.
3,990 - 4,020:	Reddish brown and creamy white sandstone with argillaceous cement, grains poorly sorted.
4,020 - 4,060:	Chocolate brown and dark grey silty shale, micaceous.
4,060 - 4,140:	Creamy grey sandstone, with argillaceous cement, fine grained.

Depth in Meters	Lithologic Descriptions
4,140 - 4,170:	Chocolate brown and dark grey sandy shale and siltstone.
4,170 - 4,170:	Greyish white sandstone, medium grained, calcareous.
4,170 - 4,450:	Dark grey and chocolate brown silty shale, siltstone, sandy shale, brittle.
4,450 - 4,510:	Grey white sandstone, grains angular, poorly sorted, calcareous.
4,510 - 4,560:	Missing interval
4,560 - 4,570:	Greyish white coarse grained sandstone, poorly sorted.
4,570 - 4,585:	Dark grey and chocolate brown shale.
4,585 - 4,615:	Greyish sandstone, coarse grained, grains angular, poorly sorted.
4,615 - 4,630:	Dark grey and chocolate brown shaly sandstone and siltstone.
4,630 - 4,730:	Greyish white sandstone, medium to coarse grained, angular, poorly sorted.
4,730 - 4,800:	Dark grey and chocolate brown shaly sandstone, sandy shale and siltstone interbeddings.
4,800 - 4,830:	Greyish white sandstone, fine to medium grained, poorly sorted.

Depth in Meters	Lithologic Descriptions
4,830 - 4,845:	Dark grey and chocolate brown sandy shale.
4,845 - 4,885:	Greyish white medium to coarse grained sandstone, poorly sorted.
4,885 - 4,950:	Dark grey and chocolate shaly sandstone and siltstone.
4,950 - 4,960:	Greyish white medium grained sandstone, micaceous.
4,960 - 4,975:	Dark grey and chocolate brown shaly sandstone and siltstone, micaceous.
4,975 - 5,000:	Greyish white sandstone, coarse grained, angular, compact with occasional dark grey and chocolate brown shale at the base.
5,000 - 5,006:	Graphite and micaceous gneiss; Dahomeyan, basement.

Note: A 230-foot thickness of dolerite intrusion overlies the Paleozoic sediments. Fragments from this dolerite occur in most of the samples from this well.

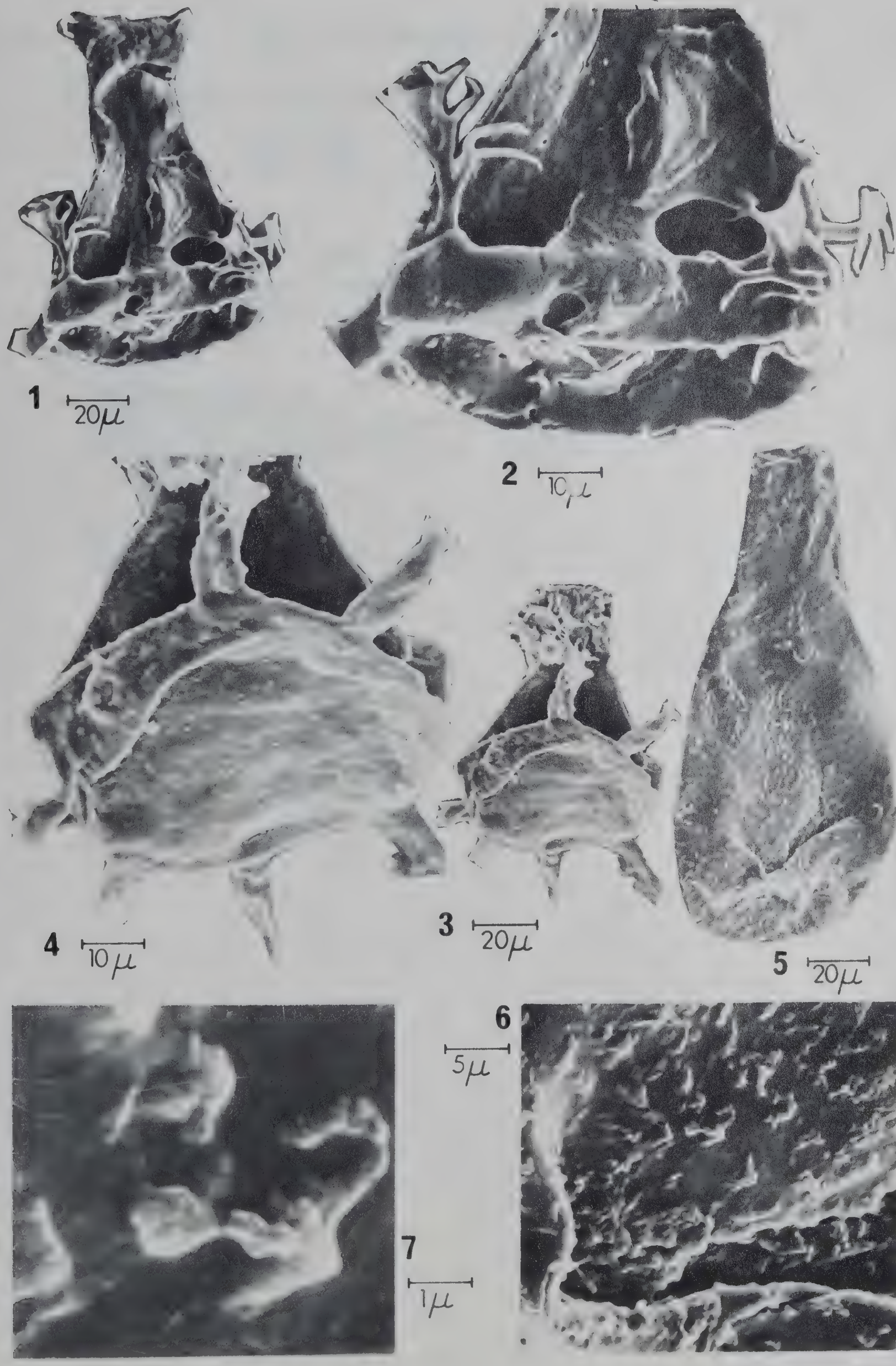
EXPLANATION OF PLATES

EXPLANATION OF PLATE I

Figure	(Scanning electron micrographs)	Page
1,2	Ancyrochitina sp. cf. A. ancyrea Eisenack Sample UC/19-2A/8500; 1, entire specimen; 2, details of multifurcate, hollow basal processes	96
3,4	Ancyrochitina tumida Taugourdeau and Jekhowsky Sample UC/19-2A/8500; 3, entire specimen; 4, details of symmetrically placed basal processes	112
5-7	Chitinozoan type B Sample SE/10-1/8220; 5, entire specimen; 6-7, details of ornamentation	186

Magnification as shown on plate.

PLATE I

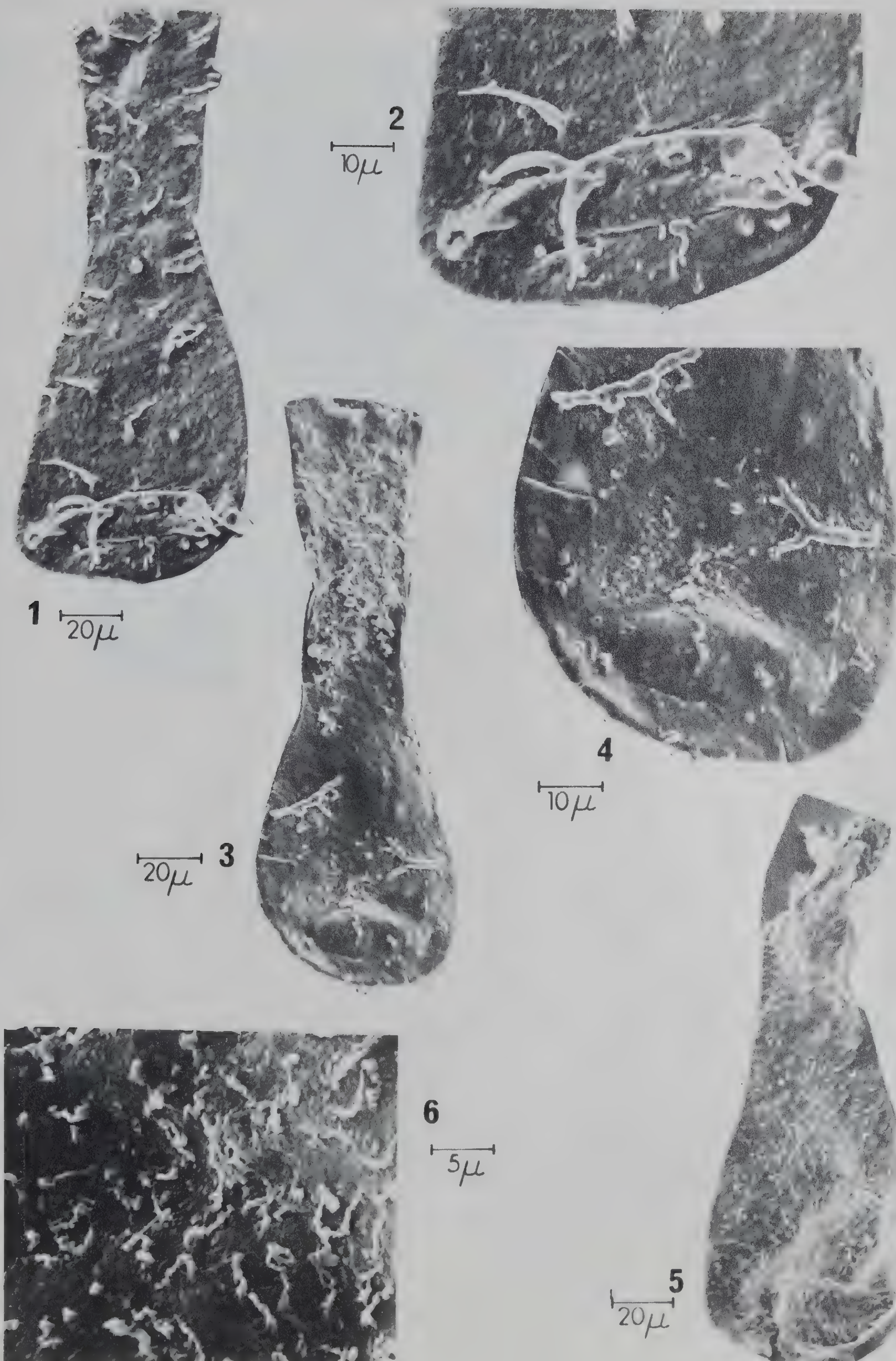


EXPLANATION OF PLATE II

Figure	(Scanning electron micrographs)	Page
1,2	Angochitina (Ramochitina) ramosi (Sommer and van Boekel) Sample A-1/1266-1268; 1, entire specimen; 2, details of hollow spines	138
3,4	Chitinozoa type E Sample A-1/1266-1268; 3, entire specimen; 4, details of part of ornamentation which consists of a network of thin strands (see Pl. XV, fig. 4, Text-fig. 18e)	190
5,6	Sphaerochitina sp. 3 Sample SE/10-1/8220; 5, entire specimen; 6, details of spinose ornamentation	182

Magnification as shown on plate.

PLATE II



EXPLANATION OF PLATE III

Figure	(All figures X240 unless otherwise stated)	Page
1-8,12, 13	Ancyrochitina sp. cf. A. ancyrea Eisenack 1, Sample UC/19-2A/9010/1, specimen devoid of the prosome; 2, Sample A-1/1336-1338/1, specimen with plug-like prosome at the base of the neck; 3, Sample SE/10-1/8250/1, specimen with annulated prosome; 4, Sample UC/19-2A/8700/2, specimen with the prosome appearing to be ejected from the neck; 5, Sample UC/19-2A/8500/1, specimen with thick multifurcate basal processes; 6, Sample A-1/1266-1268/3, specimen showing bifurcate processes on the lip; 7, Sample UC/19-2A/8260/4, specimen with spongy-textured basal processes (partly atrophied); 8, Sample UC/19-2A/8260/3; 12, Sample UC/19-2A/8350/2, specimen with alveolar-like processes on the lip; 13, Sample UC/19-2A/9010/1 (cf. 12)	96
9-11, 14-18	Ancyrochitina sp. 1 Well preserved specimens showing growth lines; body chambers high conical with short necks; 9, Sample SE/10-1/8300/5; 10, Sample SE/10-1/8300/3; 11, Sample SE/10-1/8500/1; 14, Sample SE/10-1/8600/4; 15, Sample A-1/1298-1300/3; 16, Sample A-1/1298-1300/3; 17, Sample A-1/1298-1300/1; 18, Sample SE/10-1/8300/6	118

PLATE III

EXPLANATION OF PLATE IV

Figure	(All figures magnified X240 unless otherwise stated)	Page
1-5,7, 8	<u>Ancyrochitina</u> <u>striata</u> Taugourdeau Well preserved specimens showing distinct folding of the wall along the vertical axis of the text; 1, Sample SE/10-1/8400/1, specimen showing simple, tapering, basal processes; many of the specimens recovered were without the basal processes; 1, prosome lost; 2-4, with annulated prosomes; 5, with short plug-like prosome; 2, Sample A-1/1318-1320/1; 3, Sample A-1/1318-1320/2; 4, Sample A-1/1318-1320/4; 5, A-1/1266-1268/1; 7, Sample UC/19-2A/8260/2; 8, Sample UC/19-2A/8290/3, specimen showing criss-crossed folding of the test	99
6	<u>Ancyrochitina</u> sp. 1 Sample UC/19-2A/8260/2	118
9-12	<u>Ancyrochitina</u> sp. cf. <u>A</u>. <u>cornigera</u> Collinson and Scott 9, Sample UC/19-2A/8350/4; 10, Sample UC/19-2A/9010/2, specimen with the base split open and showing body cavity; 11, Sample UC/19-2A/8350/1, short variety of the species; 12, Sample UC/19-2A/9010/4, specimen with short tapering basal processes which are curved toward the base	101
13	<u>Ancyrochitina</u> <u>tumida</u> Taugourdeau and Jekhowsky Sample UC/19-2A/8700/1	112
14-16.	<u>Ancyrochitina</u> sp. cf. <u>A</u>. <u>desmea</u> Eisenack 14, 15, Sample SE/10-1/8500/3; 15, details of ramified basal processes, magnification X 380 ; 16, Sample SE/10-1/8850/2	111

PLATE IV

EXPLANATION OF PLATE V

Figure	(All figures magnified X240 unless otherwise stated)	Page
1-4	Ancyrochitina langei Sommer and van Boekel 1, Sample UC/19-2A/8550/1, specimen with simple tapering basal processes and thick, spine-like processes on the lip; 2, Sample UC/19-2A/9010/3, specimen with bifurcate, long basal processes; 3, Sample UC/19-2A/8500/5; 4, Sample UC/8880/1	103
5-7	Ancyrochitina sp. cf. A. gumersinda Cramer 5, Sample UC/19-2A/8880/4, specimen with disproportionately long neck; 6, UC/19-2A/9010/1, and 7, Sample UC/19-2A/8880/1, specimens intermediate between A. gumersinda typical forms and A. langei	105
8-11	Ancyrochitina sp. 6 8, Sample UC/19-2A/8880/1, specimen showing distinct constriction at the junction of the neck and body chamber; 9, Sample UC/19-2A/9010/3, specimen with distinct translucent lip; 10, Sample A-1/1442-1444/1, specimen with incipient constriction at the junction of neck and body chamber; 11, Sample UC/19-2A/8900/4, specimen with constriction at the lip. A. sp. 6 differs from Cladochitina biconstricta Lange (from the Lower Devonian of Brazil which has somewhat similar shape of the test) by the lack of ornamentation of the body (in A. sp. 6)	125
12-14	Alpenachitina eisenacki Dunn and Miller 12, Sample UC/19-2A/8550/2, poorly preserved specimen showing rows of spines at the basal edge and on the chamber; 13, Sample UC/19-2A/8480/2; 14, Sample UC/19-2A/8500/6	92
15-16	?Alpenachitina sp. 1 15, Sample A-1/1266-1268/2, specimen showing a cluster of spine bases on the upper part of the body chamber; 16, Sample UC/19-2A/8550/2	94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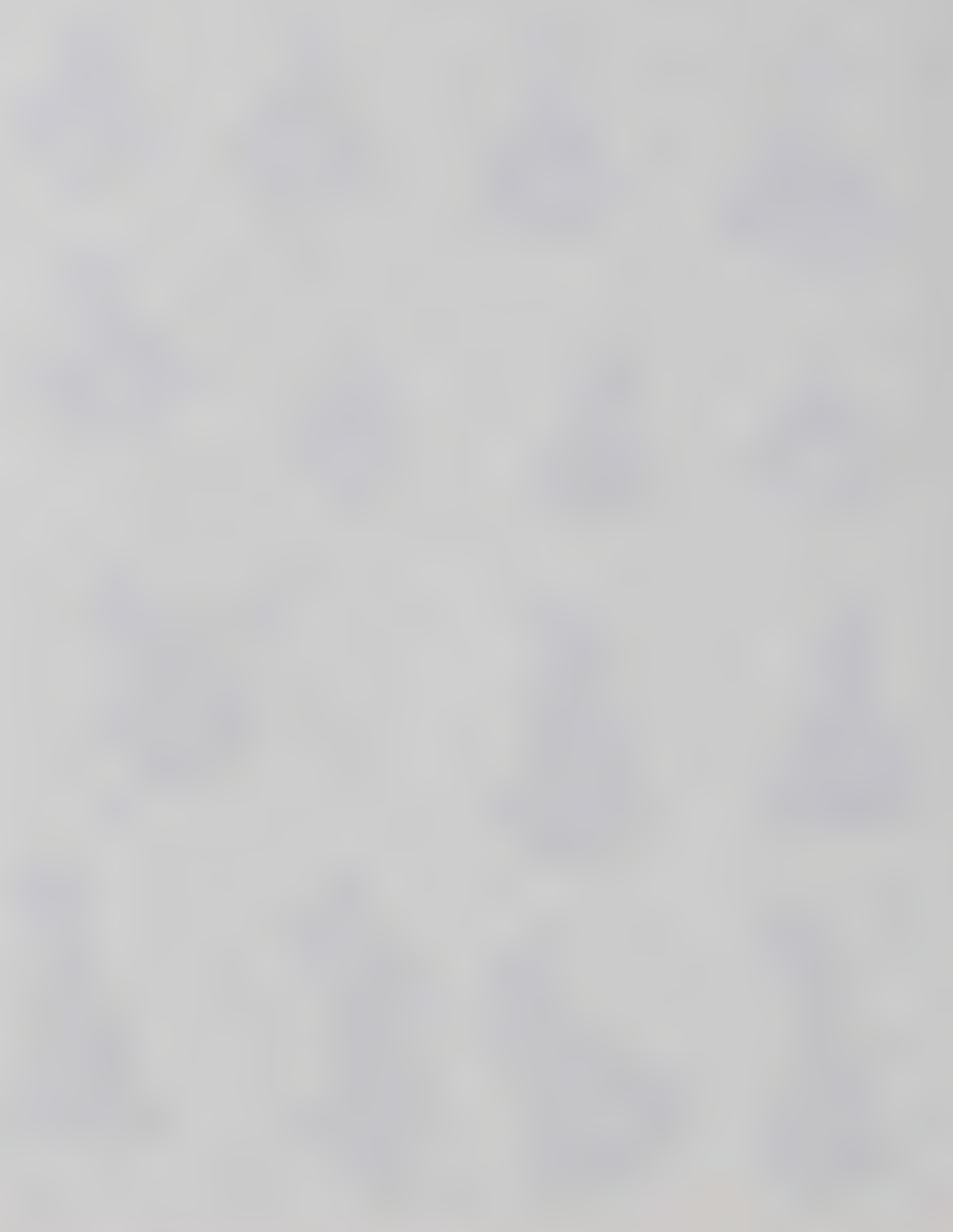
EXPLANATION OF PLATE VI

Figure	(All figures magnified X240 unless otherwise stated)	Page
1-8	Ancyrochitina sp. 2 Body chamber globular or sub-globular with variously shaped basal processes; 1, Sample UC/19-2A/8700/1, specimen with simple, tapering and knob-tipped basal processes; 2, Sample UC/19-2A/9010/3, specimen with chisel shaped basal processes; 3, Sample A-1/1488-1490/1, specimen with bifurcate basal processes; 4, Sample UC/19-2A/9010/4, and 5, Sample UC/1902A/8700/3, specimens with short, simple, spine-like basal processes; 6, Sample UC/19-2A/8350/2, and 7, Sample UC/19-2A/9050/2, specimens with long, simple, tapering basal processes; 8, Sample SE/10-1/8700/2, specimen with clavate basal processes	120
9-11	Ancyrochitina tomentosa Taugourdeau and Jekhowsky 9, Sample SE/10-1/8300/1; 10, Sample SE/10-1/8300/1; 11, Sample SE/10-1/8300/2	107
12-14	Ancyrochitina sp. 7 12, Sample SE/10-1/8700/1; 13 and 14, Sample SE/10-1/8700/1; 13, entire specimen; 14, details of ornamentation and basal processes X380	126
15	?Ancyrochitina sp. 4 Sample UC/19-2A/8500/6	123

PLATE VI



EXPLANATION OF PLATE VII

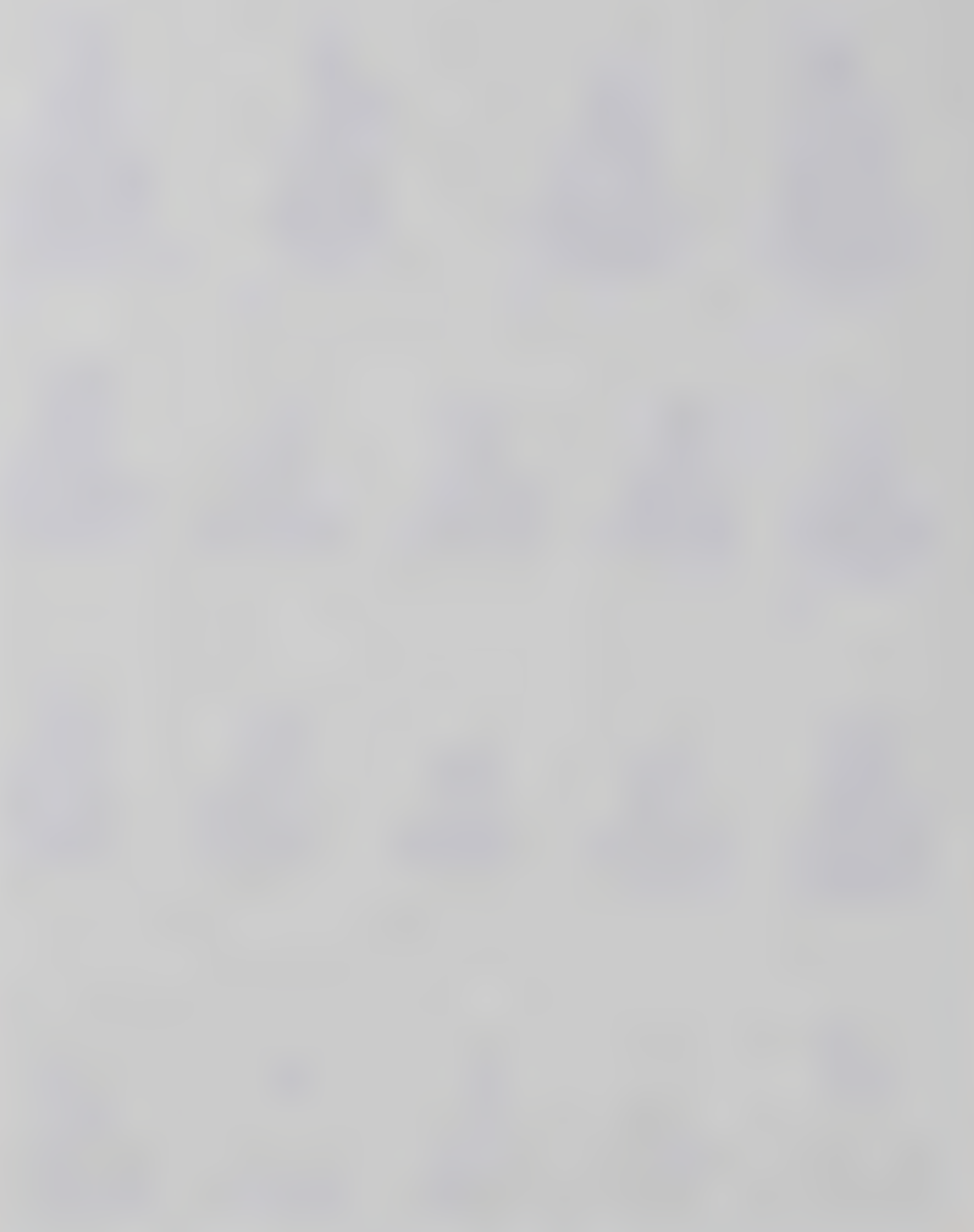
Figure	(All figures magnified X240 unless otherwise stated)	Page
1-12, 14, 15	Ancyrochitina sp. 3 Most specimens of this species recovered from the wells had their basal processes broken off. 1, Sample UC/19-2A/8350/2, specimen showing simple, elongate, tapering basal processes; 2, Sample A-1/1350-1352/1, and 3, Sample A-1/1450-1452/1, specimens with plug-like prosome at the base of the neck; 4, Sample SE/10-1/8250/3, specimen with annulated prosome; 5, Sample SE/10-1/8600/3; 6, Sample UC/19-2A/8880/3; 7, Sample A-1/1298-1300/2; 8, Sample SE/10-1/8400/2; 9, Sample SE/10-1/8250/5; 10, Sample SE/10-1/8250/6; 11, Sample SE/10-1/8300/5; 12, Sample SE/10-1/8600/3; 14, Sample SE/10-1/8350/2; 15, Sample UC/19-2A/8400/2, specimen showing multifurcate basal processes	121
13, 16, 17	Ancyrochitina sp. 5 13, Sample SE/10-1/8350; 16, Sample UC/19-2A/8700/3, specimen with simple, elongated, tapeing basal processes; 17, Sample UC/19-2A/8700/3	124

PLATE VII

EXPLANATION OF PLATE VIII

Figure	(All figures magnified X240 unless otherwise stated)	Page
1-4	Ancyrochitina sp. cf. A. spinosa Eisenack 1, Sample UC/19-2A/8290/4; 2, Sample SE/10-1/8600/4; 3, Sample UC/19-2A/9010/4; 4, Sample UC/19-2A/9010/2 ..	109
5-19	Ancyrochitina sp. cf. A. sp. Jansonius 5-9, specimens with short cylindrical necks; 5, Sample UC/19-2A/8380/3; 6, Sample UC/12-2A/9010/3; 7, Sample A-1/1298-1300/4; 8, Sample A-1/1298-1300/5; 9, Sample UC/19-2A/8380/3; 10-14, specimens with short flaring necks, 10, Sample UC/19-2A/8290/1; 11, Sample UC/19-2A/9010/3; 12, Sample SE/10-1/9050/1; 13, Sample SE/10-1/8220/5; 14, Sample UC/8380/3; 15-18, specimens with sparsely distributed fine spines; 15, Sample SE/10-1/8300/4; 16, Sample SE/10-1/8300/5; 17, Sample A-1/1298-1300/1; 18, Sample A-1/1298-1300/4; 19, specimen with coarse spines, Sample SE/10-1/9000/5	114

PLATE VIII



EXPLANATION OF PLATE IX

Figure	(All figures magnified X240 unless otherwise stated)	Page
1-9	Cladochitina varispinosa Lange 1-3, specimens with thick, bifurcate and multifurcate spines, 1, Sample UC/19-2A/8500/4; 2, Sample UC/19-2A/8500/4; 3, Sample UC/19-2A/8650/2; 4, specimen showing spine bases, Sample UC/19-2A/8650/2; 5, specimen with simple, short spines and multibranched basal processes (see Text-fig. 18e), Sample UC/19-2A/8650/1; 6, Sample UC/19-2A/8550/1; 7, same as 6 darkened to show details of the spines; 8 and 9, specimen with most of the spines abraded, 8, Sample UC/19-2A/8650/2; 9, Sample UC/19-2A/8600/2	152
10-16	Ancyrochitina sp. 1 Specimens with hispid to scaley ornamentation; 10, specimen with plug-like prosome, Sample A-1/1404-1406/1; 11, specimen with annulated prosome, Sample A-1/1298-1300/4; 12, Sample A-1/1318-1320/4; 13, specimen with simple, elongated tapering basal processes, Sample A-1/1450-1452/2; 14, Sample A-1/1298-1300/5; 15, Sample A-1/1298-1300/4; 16, Sample A-1/1318-1320/4.	118

PLATE IX

EXPLANATION OF PLATE X

Figure	(All figures magnified X240 unless otherwise stated)	Page
1-3, 6-11	Angochitina devonica Eisenack 1, Sample UC/19-2A/8250/2; 2, Sample SE/10-1/8700/1; 3, Sample A-1/1298-1300/5; 6, Sample SE/10-1/8300/4; 7, Sample SE/10-1/8300/1; 8, Sample SE/10-1/8300/2; 9, Sample SE/10-1/8300/3; 10, Sample SE/10-1/8300/1; 11, Sample SE/10-1/8300/6	130
4,5	Angochitina sp. cf. A. devonica Eisenack Specimens with elongated ovoid body chambers and broad flexures, 4, Sample A-1/1406-1462/1; 5, Sample A-1/1224-1226/3	132
12,13	Angochitina callawayensis Urban and Kline 12, specimen with simple spines arranged in vertical rows, two rows of spines may converge near the shoulder and continue orally as a single row of spines, Sample A-1/1286-1288/2; 13, specimen with bifurcate spines arranged in vertical rows as above, Sample A-1/1286-1288/2	133
14-17	?Ancyrochitina sp. cf. A. aequoris Urban and Kline 14, 15, specimens with multifurcate flattened spines vertically arranged; 14, Sample A-1/1298-1300/3; 15, Sample A-1/1286-1288/3; 16-17, specimens with multifurcate flattened spines randomly arranged; 16, Sample A-1/1286-1288/2; 17, Sample A-1/1522-1524/1	116

PLATE X

EXPLANATION OF PLATE XI

Figure	(All figures magnified X240 unless otherwise stated)	Page
1,2	*Angochitina* sp. 4 1, Sample A-1/1266-1268/1; 2, Sample UC/19-2A/8350/2	150
3	Chitinozoan type B Sample SE/10-1/8220/2	186
4,5,6, 8,9,11, 12,15	*Angochitina* sp. cf. *A. capillata* Eisenack 4-6, specimens showing lack of spinose ornamentation on the lip. 4, Sample SE/10-1/8000/1; 5, Sample UC/19-2A/8700/1; 6, contracted specimen, Sample UC/19-2A/8310/1; 8, specimen with reduced spinose ornamentation on the lip, Sample UC/19-2A/8700/2; 9, specimen contracted at the base, Sample UC/19-2A/8700/1; 11, specimen with plug-like prosome, Sample UC/19-2A/8950/2; 12, specimen with annulated prosome, Sample UC/19-2A/8700/2; 15, specimen disoriented on slide giving a false impression of globular body chamber, Sample UC/19-2A/8650/1	134
10,14	*Angochitina* sp. cf. *A. bifurcata* Collinson and Schwalb 10, Sample UC/19-2A/8400/1; 14, Sample UC/19-2A/8700/3	144
13, 17	*Angochitina mourai* Lange 13, Sample SE/10-1/8220/3; 17, Sample UC/19-2A/8700/1	136
7	*Angochitina* sp. 2 Sample UC/19-2A/8880/4	148
16.	?*Conochitina* sp. 3 Sample UC/19-2A/8400/1	157

PLATE XI

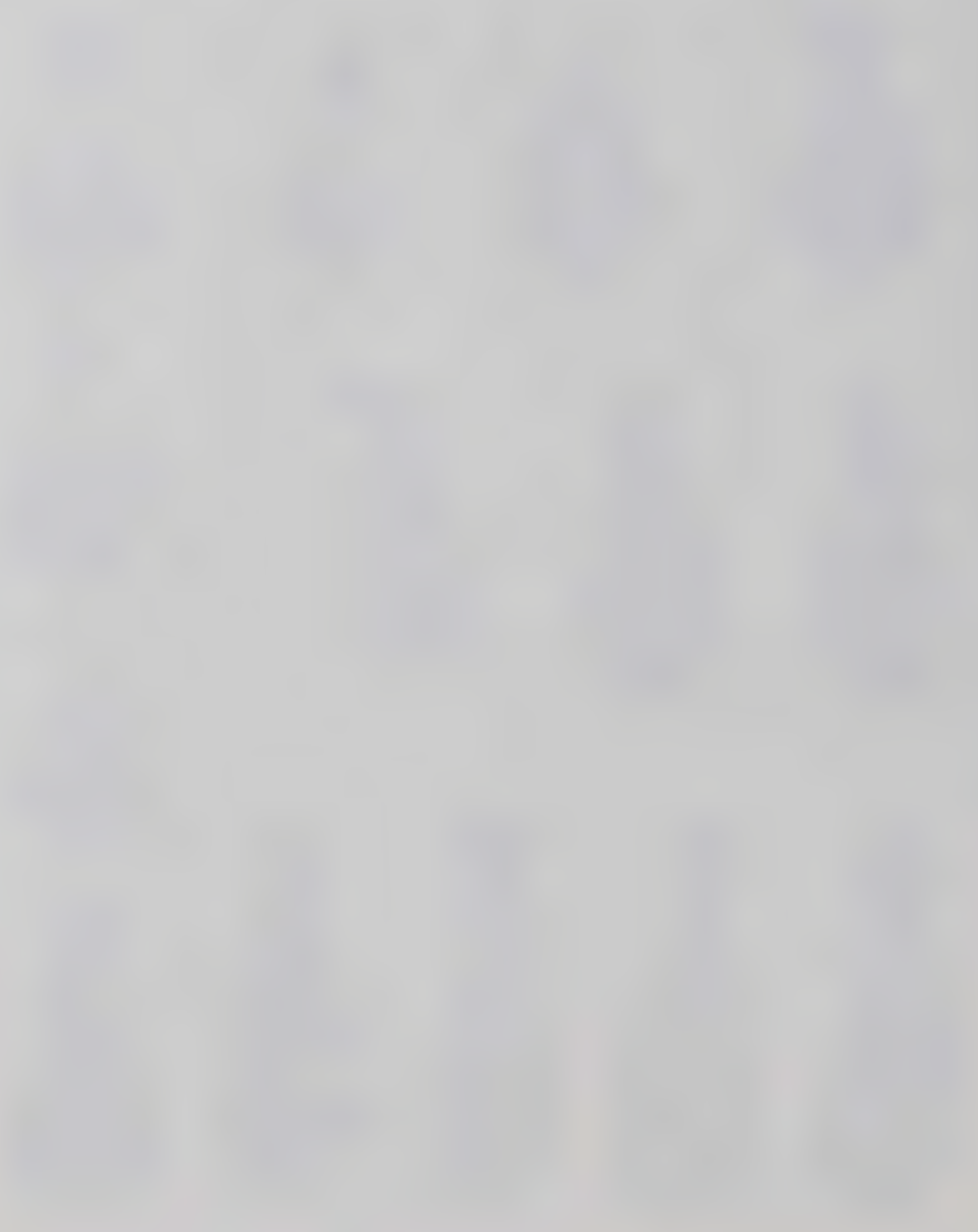
EXPLANATION OF PLATE XII

Figure	(All figures magnified X240 unless otherwise stated)	Page
1-2, 6-17	Angochitina (Ramochitina) ramosi (Sommer and van Boekel) 1,2, specimens with fairly long necks, 1, Sample UC/19-2A/8290/2; 2, Sample UC/19-2A/8310/4; 6-17 specimens with short necks and showing variations in body chamber which varies from cylindro-ovoid to sub-globular; spine size and distribution also variable; 6, Sample A-1/1298-1300/3; 7, same as 6, darkened to show spine profile; 8, Sample A-1/1350-1352/1; 9, Sample A-1/1450-1452/1; 10, Sample A-1/1460-1462/1; 11, Sample A-1/1298-1300/3; 12, Sample A-1/1266-1268/2; 13, Sample A-1/1298-1300/5; 14, Sample A-1/1298-1300/4; 15, Sample A-1/1298-1300/1; 16, Sample A-1/1298-1300/1; 17, Sample A-1/1266-1268/3	138
3-5	Angochitina sp. 1 3, Sample UC/19-2A/8600/1; 4, Sample SE/10-1/8700/1; 5, same as 4, darkened to show profile of spines	147

EXPLANATION OF PLATE XIII

Figure	(All figures magnified X240 unless otherwise stated)	Page
1-5	*Angochitina mourai* Lange 1-4, specimens showing uniform increase in spine size; 1, Sample SE/10-1/8220/3; 2, Sample SE/10-1/8220/4; 3, Sample SE/10-1/8220/1; 4, Sample SE/10-1/8220/3; 5, Sample A-1/1226-1228/2	136
6,7	*Angochitina* sp. 3 6, Sample SE/10-1/8220/5; 7, Sample SE/10-1/8220/5 ...	149
8	*Angochitina* sp. cf. *A. comosa* Taugourdeau and Jekhowsky Sample SE/10-1/8000/1	143
9	Chitinozoan sp. Sample A-1/1404-1406/2 (single specimen observed not described)	
10,11, 13	*Lagenochitina* sp. cf. *L. amottensis* Grignani and Mantovani 10, Sample SE/10-1/8000/4; 11, Sample A-1/1286-1288/5; 13, Sample A-1/1404-1406/1	167
12	*Angochitina comosa* Taugourdeau and Jekhowsky Sample SE/10-1/8000/6	142
14	*Angochitina* sp. 2 Sample SE/10-1/8000/5	148

PLATE XIII



EXPLANATION OF PLATE XIV

Figure	(All figures magnified X240 unless otherwise stated)	Page
1-4	Sphaerochitina sp. 1 1, two specimens in a chain formation, Sample SE/10-1/8250/3; 2, Sample UC/19-2A/8600/2; 3-4, specimens folded at the base; 3, Sample UC/19-2A/8600/2; 4, Sample UC/19-2A/8800/4	180
5,6,8, 9,11, 14,15	Sphaerochitina schwalbi Collinson and Scott 5, Sample SE/10-1/8300/3; 6, Sample SE/10-1/8300/4; 8, Sample SE/10-1/8300/4; 9, Sample SE/10-1/8220/3; 11, Sample UC/19-2A/9010/3; 12, Sample A-1/1286-1288/3; 14, Sample UC/19-2A/8700/4; 15, Sample UC/19-2A/8600/2; 16, Sample UC/19-2A/8650/2	176
7,10, 13,17	Sphaerochitina sp. 2 7, Sample UC/19-2A/8700/1; 10, Sample UC/19-2A/8700/1; 13, Sample UC/19-2A/8700/1; 17, Sample A-1/8250/4	181
18-21	Sphaerochitina pilosa Collinson and Scott 18, Sample UC/19-2A/9010/4; 19, Sample UC/19-2A/8290/5; 20, A-1/1404-1406/1; 21, Sample UC/19-2A/9010/3	174
22	Sphaerochitina sp. cf. S. pilosa Collinson and Scott Sample UC/19-2A/8700/1, a variety of S. pilosa with an inflated body chamber, one specimen observed (not described).	

PLATE XIV

EXPLANATION OF PLATE XV

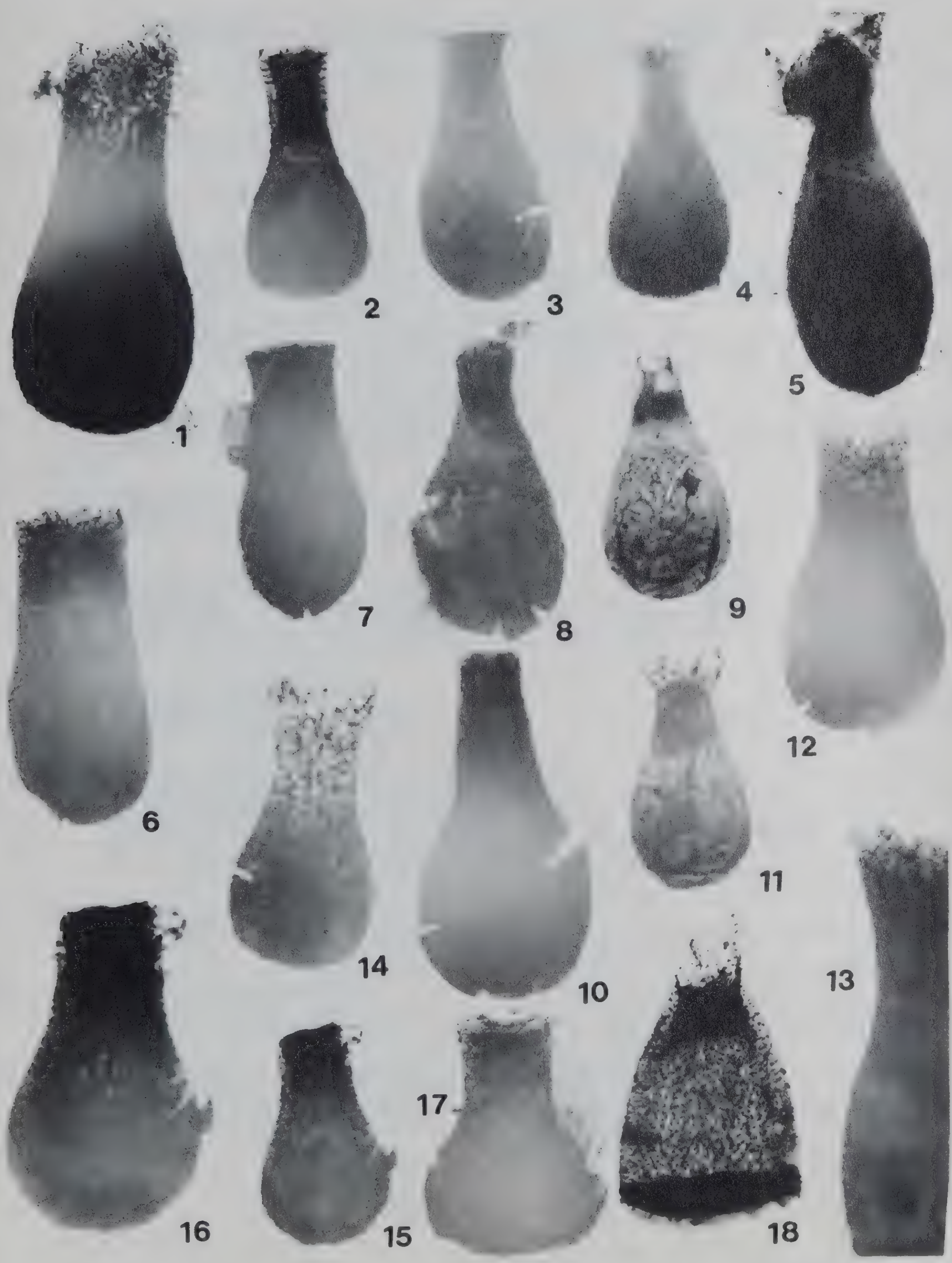
Figure	(All figures magnified X240 unless otherwise stated)	Page
1,5-8, 11,13-15	Sphaerochitina sp. 3 1, Sample UC/19-2A/8650/1; 5,6, Sample SE/10-1/8250/5; 6, details of the prosome megnification X380; 7, Sample SE/10-1/8250/4; 8, Sample SE/10-1/8220/1; 11, Sample A-1/1454-1456/1; 13, Sample SE/10-1/8750/2; 14, Sample A-1/1454-1456/1; 15, Sample A-1/1454-1456/	182
2-4	Chitinozoan type E 2, specimen with long neck, ornamentation eroded, Sample A-1/1266-1268/2; 3, specimen with "medium" neck, ornamentation partly eroded, Sample A-1/1266-1268/1; 4, specimen with short neck and part of the ornamentation on neck, Sample A-1/1298-1300/1	190
9,10	Sphaerochitina sphaerocephala Eisenack 9, specimen devoid of the prosome, Sample SE/10-1/8250/2; 10, specimen with the prosome appearing to be ejected from the neck, Sample SE/10-1/8220/4	172
12	Sphaerochitina brevispinosa Grignani and Mantovani Sample SE/10-1/8000/4	177

PLATE XV

EXPLANATION OF PLATE XVI

Figure	(All figures magnified X240 unless otherwise stated)	Page
1,12, 13,17, 18	Chitinozoan type B 1,Sample SE/10-1/8220/2; 12, 13, Sample SE/10-1/ 8220/4; 13, details of ornamentation, magnification X (cf. Pl. I, figs. 5-7); 17, Sample SE/10-1/ 8220/3; 18, Sample SE/10-1/8300/6	186
2,3,4	_Sphaerochitina_ sp. cf. _S. cuvillieri_ Taugourdeau 2, Sample SE/10-1/8000/3; 3, Sample SE/10-1/8000/2; 4, Sample A-1/1266-1268/3	178
5,8, 9,10	Chitinozoan type A 5, Sample SE/10-1/8220/4; 8, Sample UC/19-2A/ 8150/3; 9, specimen with the ornamentation eroded, Sample UC/19-2A/8600/2; 10, Sample SE/10-1/8220/3	185
6,7	Chitinozoan type C 6, Sample A-1/1522-1524/2; 7, Sample SE/10-1/8700/1 ..	188
11	_Angochitina_ sp. cf. _A. crumena_ Taugourdeau Sample SE/10-1/8000/4	145
14	_Angochitina_ sp. Sample SE/10-1/8000/2 (only figured specimen observed, not described)	
15,16	Chitinozoan type D 15, Sample SE/10-1/9050/6; 16 same specimen as 15, magnified X380	188

PLATE XVI



EXPLANATION OF PLATE XVII

Figure	(All figures magnified X240 unless otherwise stated)	Page
1	Fungochitina longicollis (Taugourdeau and Jekhowsky) Taugourdeau Sample UC/19-2A/9010/5	162
2.	Fungochitina sp. cf. F. pistilliformis lata Taugourdeau and Jekhowsky Sample SE/10-1/8850/1	163
3,4	Fungochitina sp. 1 3, Sample SE/10-1/8750/2; 4, Sample SE/10-1/8750/3 ...	164
5	Angochitina sp. cf. A. longicolla Eisenack Sample SE/10-1/8750/1	146
6	Angochitina mourai Lange Sample A-1/1224-1226/1	136
7	?Conochitina sp. 4 Sample UC/19-2A/8400/2	158
8,9	Ancyrochitina sp. 1 Specimens with basal processes broken; 8, Sample A-1/1350-1352/1; 9, Sample A-1/1522-1524/1	118
10	?Conochitina sp. 1 Sample UC/19-2A/7060/1	155
11,12	Ancyrochitina striata Taugourdeau Basal processes of specimens broken; 11, Sample SE/10-1/8850/4; 12, specimen showing a pyrite crystal embedded in the wall, Sample SE/10-1/8850/2	99
13,16	?Conochitina sp. 5 13, Sample UC/19-2A/8480/1; 16, Sample A-1/1442-1444/3 ..	158
14	?Conochitina sp. 2 Sample UC/19-2A/7060/2	156
15	Angochitina (Ramochitina) magnifica (Lange) Sample SE/10-1/8450/1	141

EXPLANATION OF PLATE XVIII

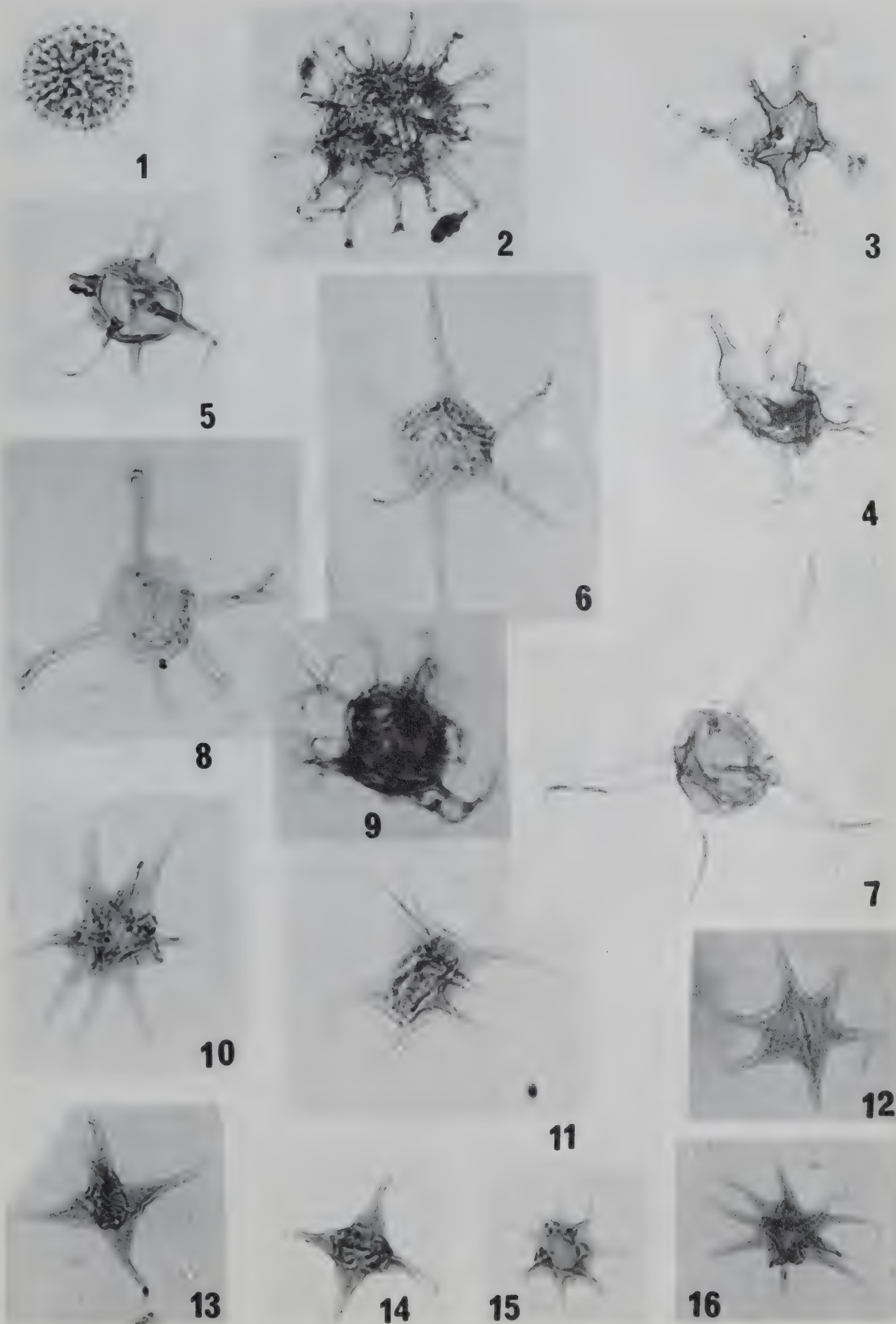
Figure	(All figures magnified X240 unless otherwise stated)	Page
1	*Rhabdochitina* sp. cf. *R. magna* Eisenack Poorly preserved specimen, Sample SE/10-1/8600/3 magnification X240	169
2	Chitinozoan type F Sample SE/10-1/9050/4	191
3	*Rhabdochitina* sp. cf. *R. claviformis* Taugourdeau Poorly preserved specimen, Sample SE/10-1/9050/4	170
4	*Desmochitina* sp. Sample SE/10-1/8450/2	159
5	*Urochitina* sp. cf. *U. bastosi* van Boekel Sample SE/10-1/8250/1	184
6-8	*Hoegisphaera glabra* Staplin 6, specimen with the operculum lost, Sample UC/ 19-2A/9010/2; 7, specimen with the operculum tilted to one side, Sample UC/19-2A/9010/3; specimen with the operculum in place, Sample UC/19-2A/9010/1	165
9	*Lagenochitina* sp. 2 Sample A-1/1224-1226/1	169
10.	*Rhabdochitina* sp. 1 Part of another test attached to the neck of this specimen; spine-like process near the base, Sample UC/19-2A/9010/5	171
11	?*Rhabdochitina* sp. Sample A-1/1460-1462/3 (only the figured specimen was observed; specimen not described)	
12,13	*Eisenackitina* sp. 1 12, specimen without the operculum, Sample A-1/ 1336-1338/3; 13, specimen with the operculum, Sample A-1/1318-1320/4	161
14	*Lagenochitina* sp. 1 Sample UC/19-2A/7700/4	168

PLATE XVIII

EXPLANATION OF PLATE XIX

Figure	(All figures magnified X660 unless otherwise stated)	Page
1	Ammonidium sp. 1 Sample UC/19-2A/8480/1	193
2.	Ammonidium sp. 2 Sample UC/19-2A/8480/1	194
3,4,9	Multiplicisphaeridium ramusculosum (Deflandre) Lister 3, Sample UC/19-2A/8480/3; 4, Sample UC/19-2A/ 8480/2; 9, Sample UC/19-2A/8480/3	203
5,7,8	Multiplicisphaeridium arbusculiferum (Downie) Staplin, Jansonius, Pocock 5, Sample UC/19-2A/8480/1; 7, Sample UC/19-2A/ 8480/4; 8, Sample UC/19-2A/8480/3	205
6	Evittia granulatispinosum (Downie) Lister Sample UC/19-2A/8480/2	197
10,11, 15,16	Micrhystridium stellatum Deflandre 10, Sample UC/19-2A/8480/1; 11, Sample UC/19-2A/ 8480/1; 15, Sample UC/19-2A/8480/1; 16, Sample UC/ 19-2A/8480/2	202
12	Veryhachium stelligerum Deunff Sample UC/19-2A/8480/1	209
13,14	Veryhachium sp. cf. V. lairdi (Deflandre) Deunff 13, Sample UC/19-2A/8480/1; 14, Sample UC/19-2A/ 8480/2	211

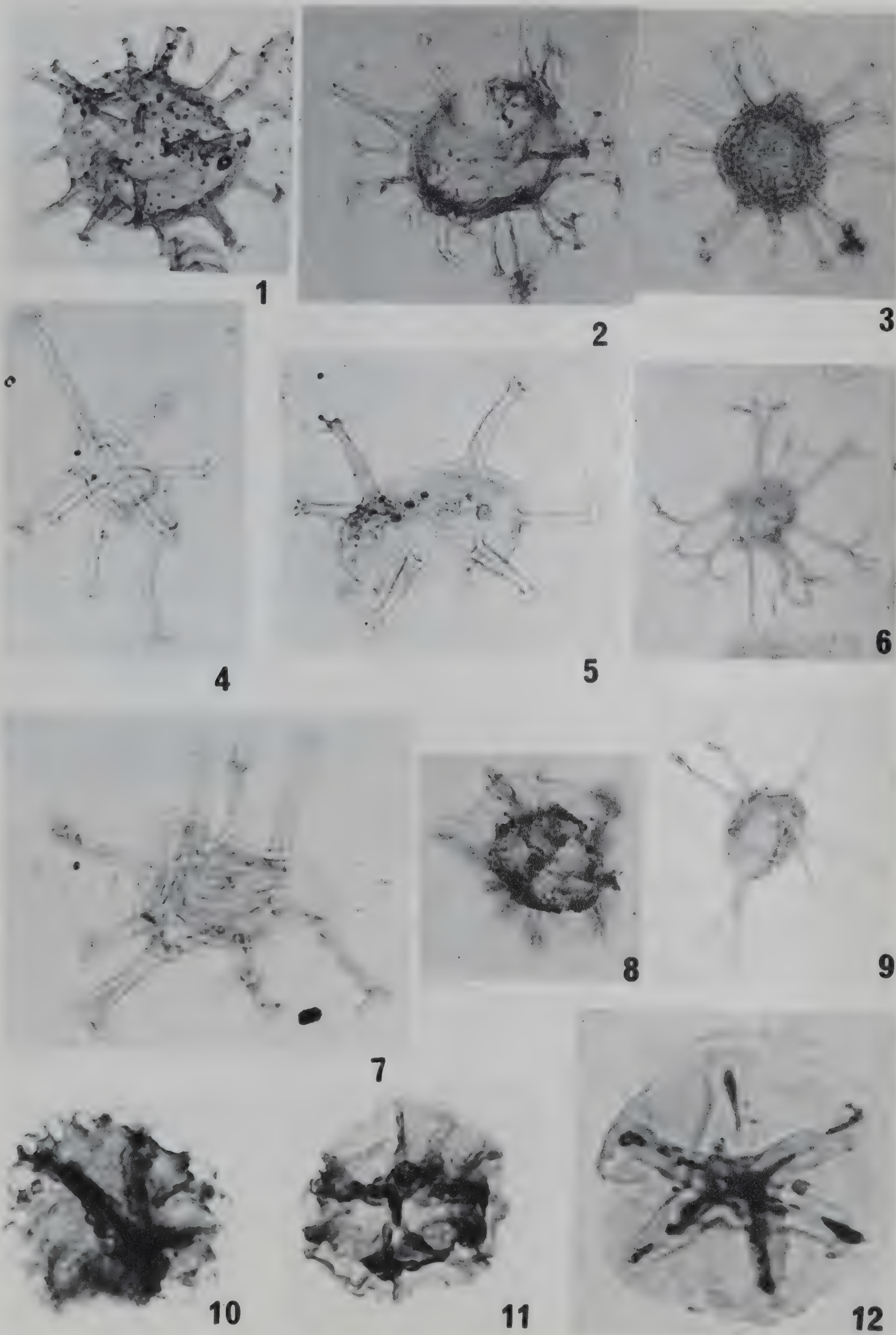
PLATE XIX



EXPLANATION OF PLATE XX

Figure	(All figures magnified X660 unless otherwise stated)	Page
1-3	Ammonidium sp. 2 1, Sample A-1/14C/2; 2, Sample UC/19-2A/7700/2; 3, Sample SE/10-1/8450/3	194
4,7	Umbellasphaeridium sp. cf. *U. saharicum* Jardiné et al. 4, Sample SE/10-1/8400/3; 7, Sample UC/19-2A/8150/2 ..	234
5	Ammonidium sp. 3 Sample UC/19-2A/8480/2	195
6	Multiplicisphaeridium ramusculosum (Deflandre) Lister Sample A-1/14C/1	203
8	?Pterospermopsis sp. Sample UC/19-2A/8480/2 (only figured specimen was observed, it was not described)	
9	?Evittia sp. 2 Sample UC/19-2A/8480/4	201
10	?Acritarch sp. Sample UC/19-2A/8480/1 (only figured specimen observed, it was not described).	
11,12	?Cymatiosphaera spp. 11, Sample UC/19-2A/8480/3; 12, Sample SE/10-1/8650/3	221

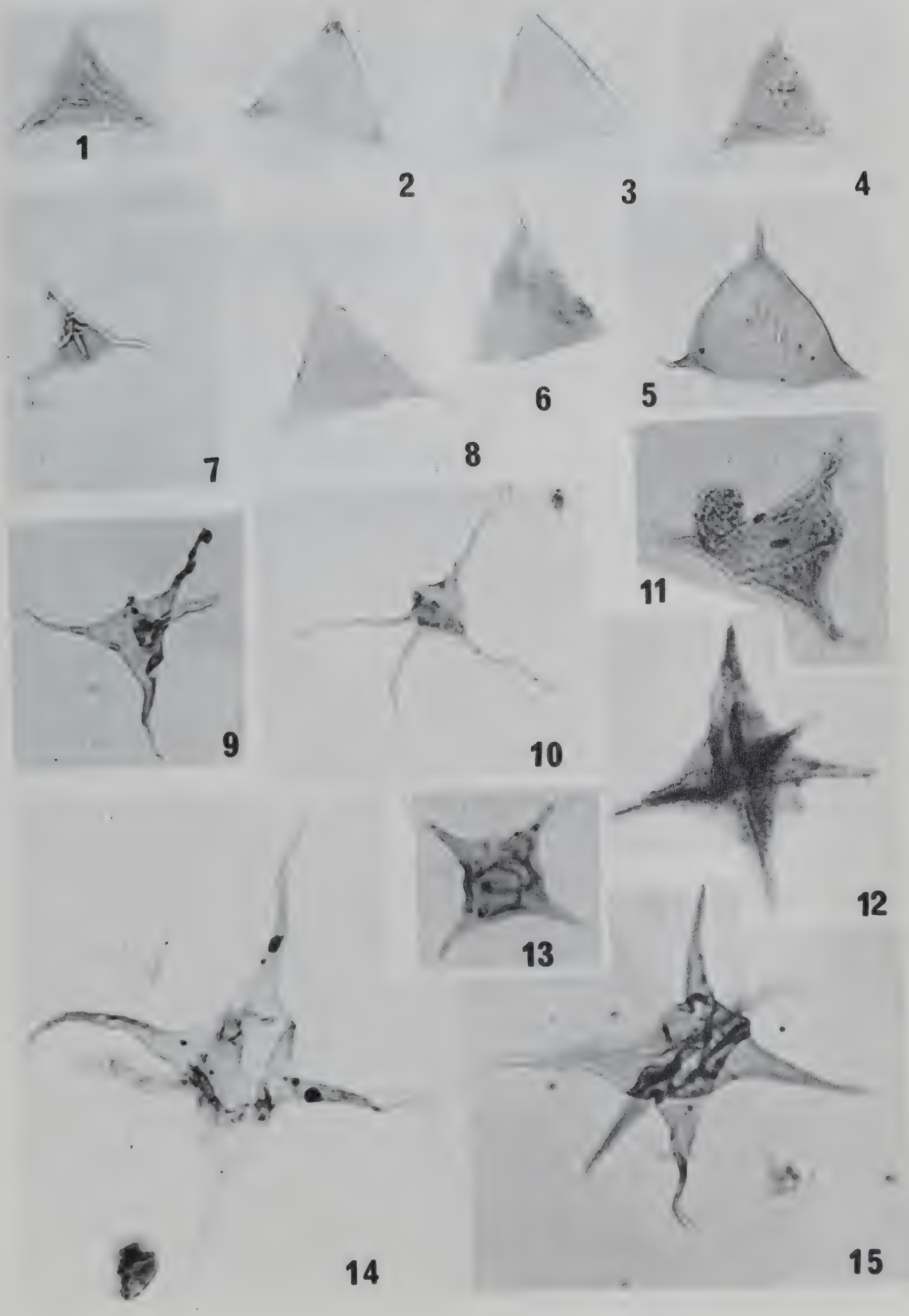
PLATE XX



EXPLANATION OF PLATE XXI

Figure	(All figures magnified X660 unless otherwise stated)	Page
1-8	Veryhachium trispinosum (Eisenack) Cramer 1, Sample UC/19-2A/9010/1; 2, Sample A-1/14C/2; 3, Sample A-1/14C/1; 4, Sample UC/19-2A/9010/1; 5, Sample UC/19-2A/8480/2; 6, Sample UC/19-2A/8480/2; 7, Sample UC/19-2A/8480/1; 8, Sample UC/19-2A/7550/1	207
9,10	Veryhachium europaeum (Stockmans and Willière) Cramer 9, Sample UC/19-2A/8480/1; 10, Sample UC/19-2A/8480/3	208
11	Acritarch sp. Sample UC/19-2A/8480/2 (only figured specimen observed, it was not described)	
12	Stellinium octoaster (Staplin) Jardiné et al. Sample UC/19-2A/8480/3	216
13	Veryhachium sp. cf. V. lairdi (Deflandre)Deunff Sample A-1/14C/1	211
14,15	Veryhachium pastoris Deunff 14, Sample UC/19-2A/8500/4; 15, Sample UC/19-2A/8950	212

PLATE XXI



EXPLANATION OF PLATE XXII

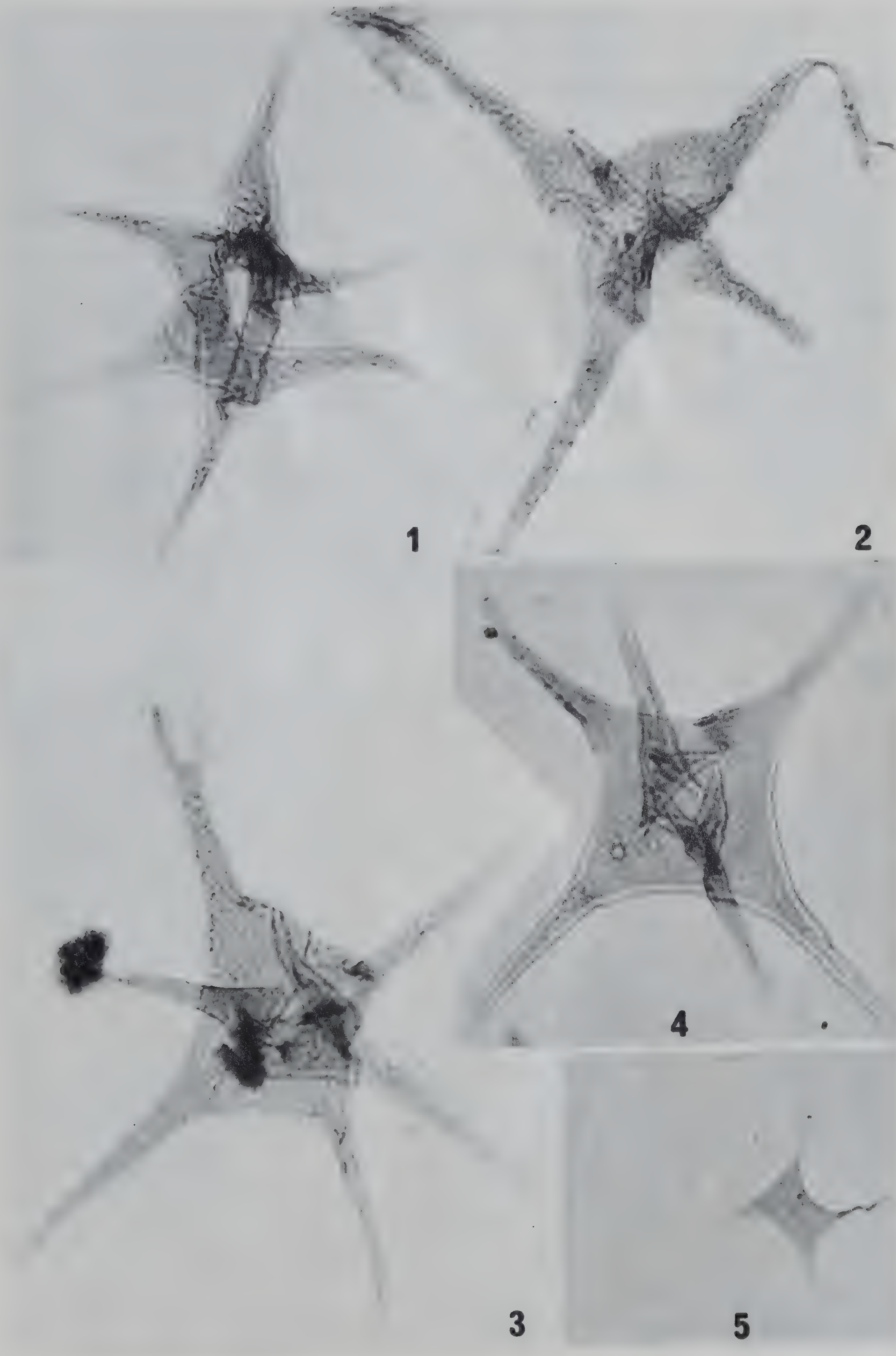
Figure	(All figures magnified X660 unless otherwise stated)	Page
1,2,4, 5	*Evittia remota* (Deunff) Lister 1, Sample UC/19-2A/8480/4; 2, Sample UC/19-2A/ 8480/1; 4, Sample UC/19/2A/8950/1; Sample UC/19-2A/ 8480/1	198
3	*Stellinium octoaster* (Staplin) Jardiné *et al.* Sample UC/19-2A/8480/1	216

PLATE XXII

EXPLANATION OF PLATE XXIII

Figure	(All figures magnified X660 unless otherwise stated)	Page
1	*Veryhachium pastoris* Deunff Sample UC/19-2A/8950/4	212
2	*Evittia* sp. 1 Sample UC/19-2A/8950/3	200
3	*Evittia remota* (Deunff) Lister Sample UC/19-2A/8480/4	198
4	*Veryhachium rabiosum* Cramer restricted Sample UC/19-2A/8480/4	213
5	*Veryhachium lairdi* (Deflandre) Deunff Sample SE/10-1/8600/1	210

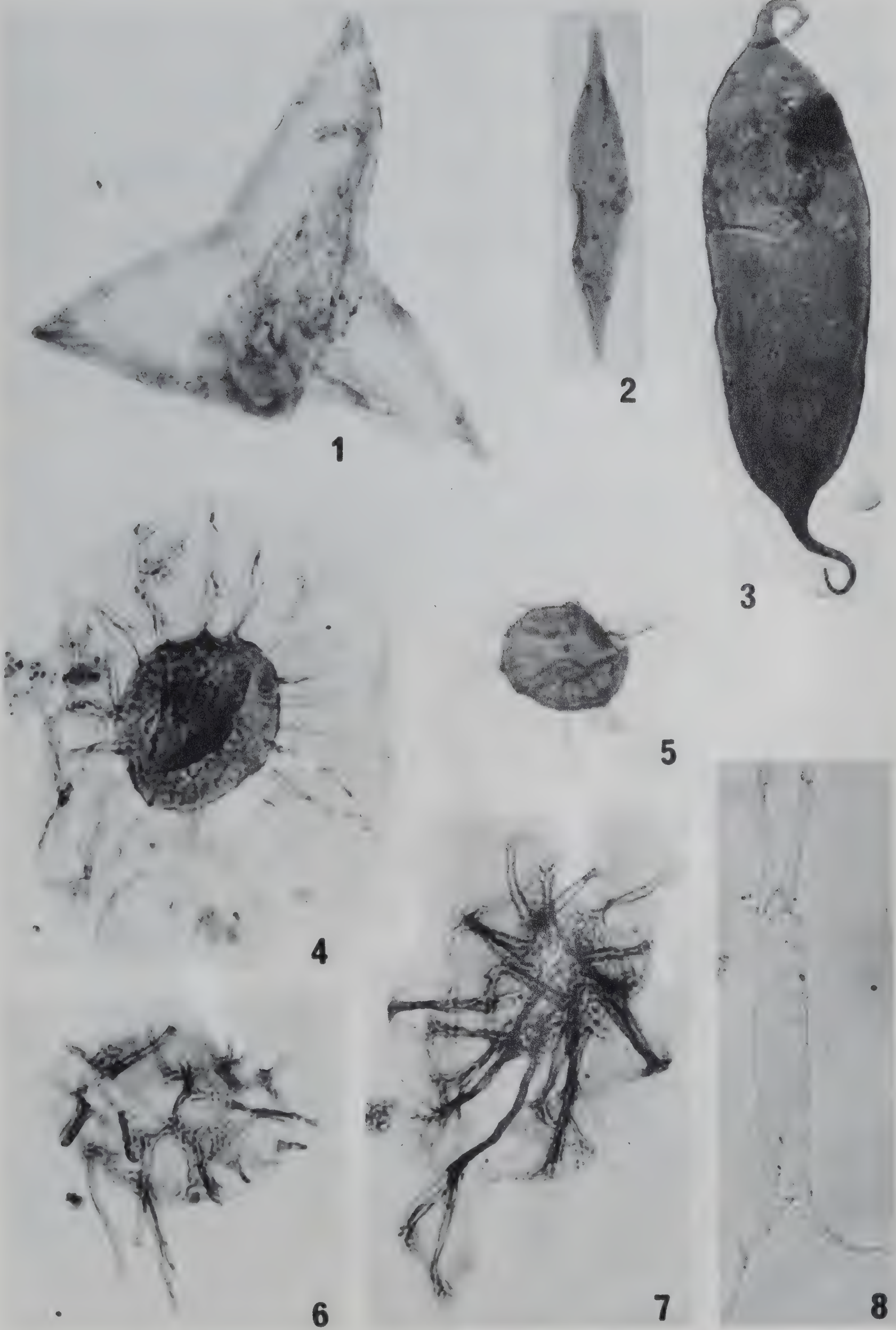
PLATE XXIII



EXPLANATION OF PLATE XXIV

Figure	(All figures magnified X660 unless otherwise stated)	Page
1	*Estiastra* sp. 1 Sample UC/19-2A/8480/3	215
2	*Leiofusa fastidiona* Cramer Sample A-1/14C/3	221
3	*Leiofusa* sp. 1 Sample UC/19-2A/9010/4	222
4	*Pterospermopsis* sp. 1 Sample UC/19-2A/8480/2	217
5	*Pteropspermopsis* sp. Sample UC/19-2A/8480/2 (only figured specimen observed, it was not described)	
6,7	*Tunisphaeridium caudatum* Deunff and Evitt 6, central body, Sample UC/19-2A/8480/1; 7, entire test, Sample UC/19-2A/8480/1	232
8	?*Leiofusa* sp. 2 Sample SE/10-1/8450/3	223

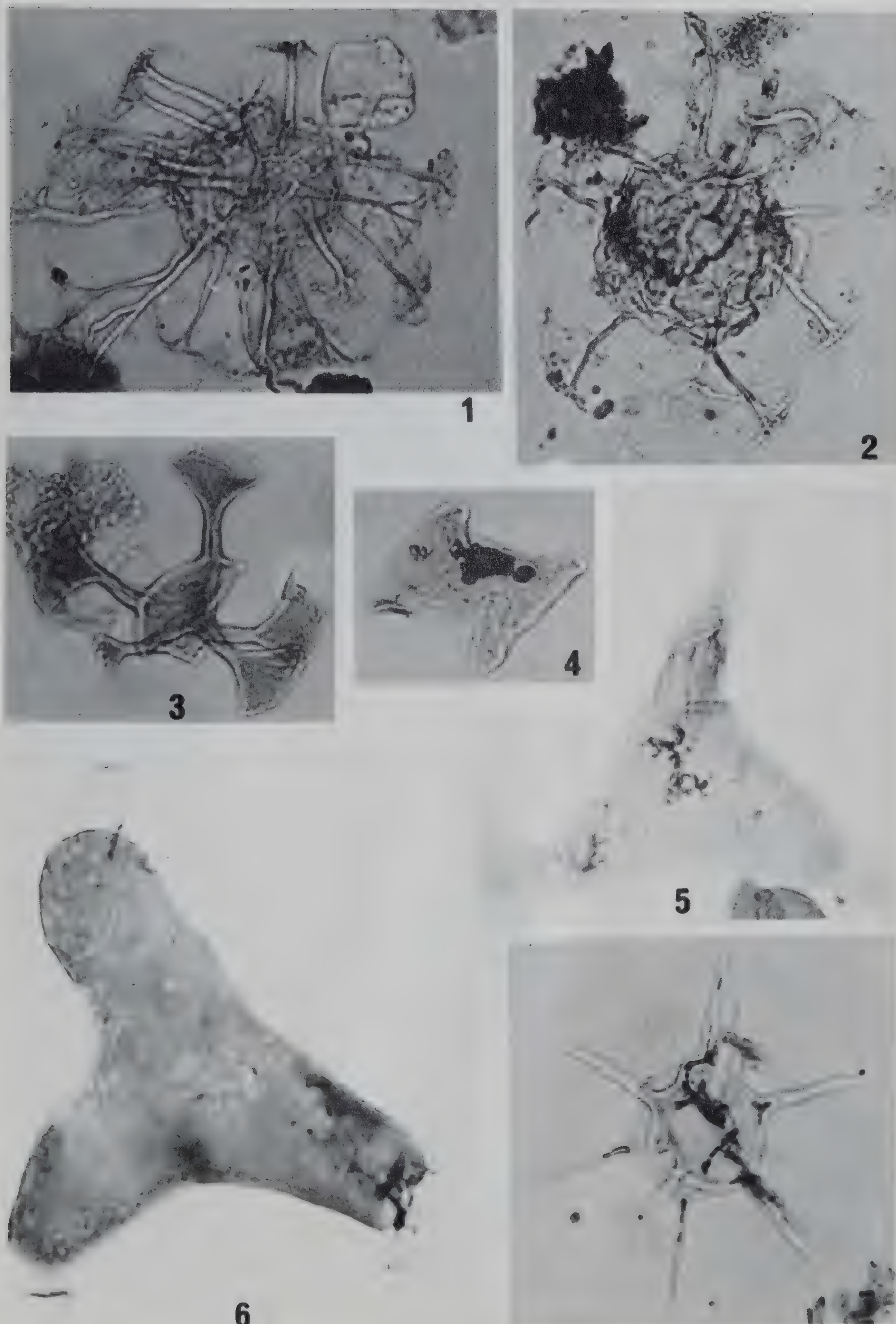
PLATE XXIV



EXPLANATION OF PLATE XXV

Figure	(All figures magnified by X660 unless otherwise stated)	Page
1	_Tunisphaeridium caudatum_ Deunff and Evitt Sample SE/10-1/8600/3	232
2	_Tunisphaeridium concentricum_ Deunff and Evitt Sample SE/10-1/8450/4	231
3	_Umbellasphaeridium saharicum_ Jardiné _et al_. Sample SE/10-1/7900/2	234
4	Forma H Sample SE/10-1/8560/4	236
5,6	_Triangulina alargada_ Cramer 5, Sample A-1/14C/1; 6, Sample UC/19-2A/8480/3	229
7	_Crameria pharoanis pharoanis_ (Deunff) Jardiné _et al_. Sample SE/10-1/8450/3	196

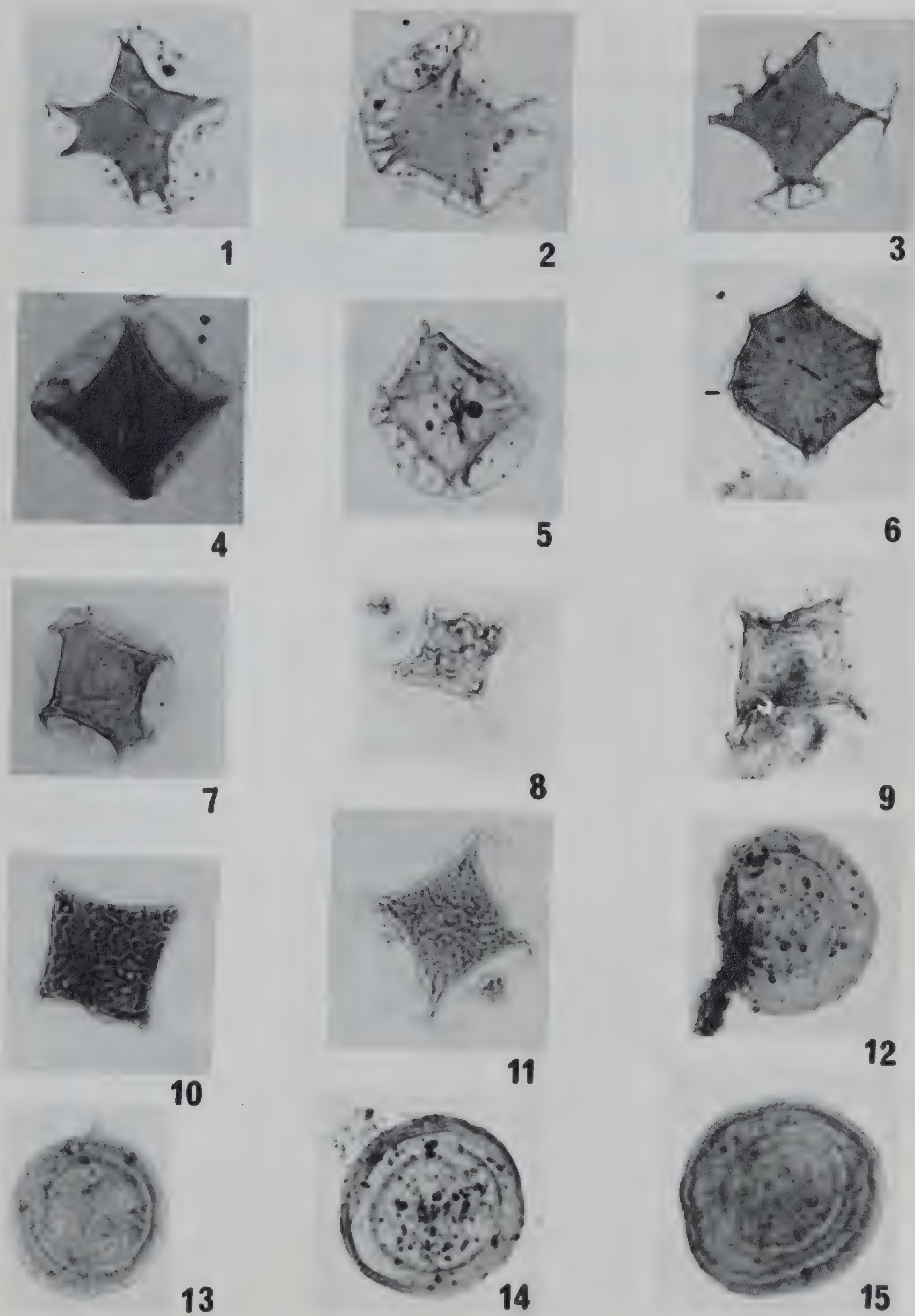
PLATE XXV



EXPLANATION OF PLATE XXVI

Figure	(All figures magnified X660 unless otherwise stated)	Page
1-11	Viliferites tenuimarginatus Brito 1, Sample A-1/14C/2; 2, Sample A-1/14C/1; 3, specimen with outer body eroded, Sample A-1/14C/1; 4, specimen with a slit-like opening in the central body, Sample A-1/14C/2; 5, Sample A-1/14C/1; 6, specimen with polygonal central body, Sample A-1/14C/1; 7, Sample UC/19-2A/8480/4; 8-11, specimens with the central body distinctly ornamented, 8, Sample; 9, Sample UC/19-2A/8480/2; 10, Sample UC/19-2A/8480/2; 11, Sample UC/19-2A/8480/2	218
12-15	Forma G 12, 13 polar views showing ring-like structure, 12, Sample A-1/14C/1; 13, Sample A-1/14C/2; 14, 15 opposite poles showing large opening, 14, Sample A-1/14C/2; 15, Sample 14C/1	235

PLATE XXVI



EXPLANATION OF PLATE XXVII

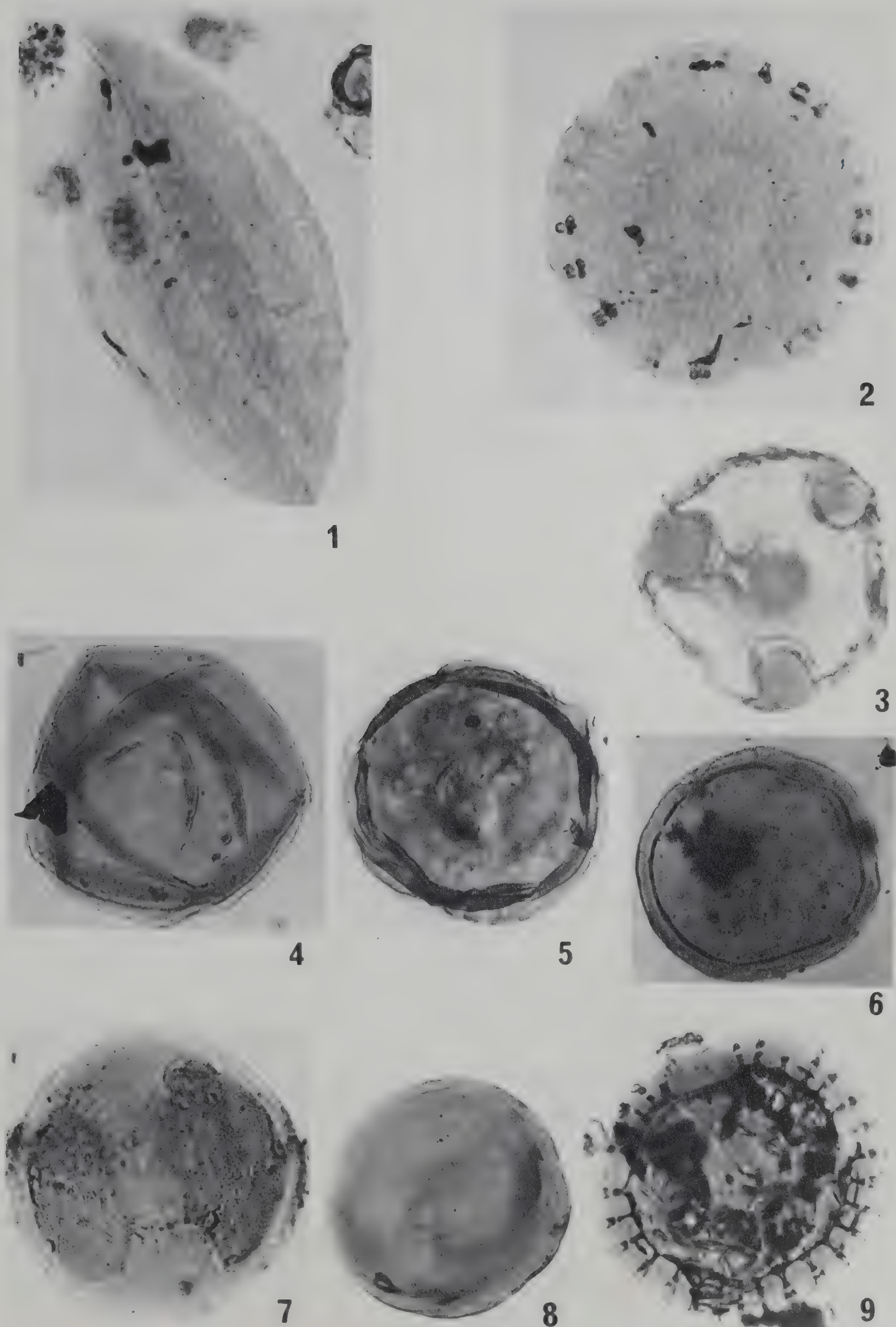
Figure	(All figures magnified X660 unless otherwise stated)	Page
1-3	*Navifusa brasiliensis* (Brito and Santos) Combaz *et al.* 1, Sample UC/19-2A/8480/4; 2, Sample UC/19-2A/8480/3; 3, Sample UC/19-2A/8480/3	224
4,5,7	*Navifusa eisenacki* (Brito and Santos) Combaz *et al.* 4, Sample UC/19-2A/8480/1; 5, Sample UC/19-2A/8480/4; 7, Sample UC/19-2A/8480/4	225
6	?*Navifusa* sp. Sample UC/19-2A/8480/4 (only the figured specimen was observed)	

PLATE XXVII

EXPLANATION OF PLATE XXVIII

Figure	(All figures magnified X660 unless otherwise stated)	Page
1	Forma J Sample SE/10-1/8600/4	
2	*Maranhites brasiliensis* Form A (Brito) Daemon *et al.* Sample SE/10-1/8700/1	227
3	*Maranhites brasiliensis* Form P (Brito) Daemon *et al.*	228
4	Leiosphere Sample UC/19-2A/8550/2	
5-9	*Tasmanites* 5, Sample UC/19-2A/7700/4; 6, Sample UC/19-2A/7700/4; 7, Sample UC/19-2A/8550/1; 8, Sample 7700/4, 9. Sample UC/19-2A/7800/1	

PLATE XXVIII



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